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**SOUNDSCAPES: THE EVOLUTION OF A CONCEPT, APPARATUS AND METHOD  
WHERE LUDIC ENGAGEMENT IN VIRTUAL INTERACTIVE SPACE IS A  
SUPPLEMENTAL TOOL FOR THERAPEUTIC MOTIVATION**

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**SOUNDSCAPES: THE EVOLUTION OF A CONCEPT, APPARATUS AND  
METHOD WHERE LUDIC ENGAGEMENT IN VIRTUAL INTERACTIVE  
SPACE IS A SUPPLEMENTAL TOOL FOR THERAPEUTIC MOTIVATION**

**ANTHONY LEWIS BROOKS**

**A thesis submitted in partial fulfilment of the requirements of the  
University of Sunderland for the degree of PhD by Existing Published or  
Creative Works**

**Faculty of Arts, Design and Media  
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## Declaration

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A statement to my objectives of the research is included in the commentary. The commentary also states to the significant and coherent contribution to knowledge at the time of submission in context to current understanding in the field and the impact of the publications. Further the commentary details the research methodologies that I regard as appropriate.

Signature: Anthony Lewis Brooks .....(December 2005)

N.B. The PhD viva was March 2006 (Pass with minor amendments). The required amendments were (at the insistence of the Sunderland examiner) that all references to "art" and "performance art" were extracted from the original document despite the author's arguments that these aspects are core to the work originating a sensor-centred interactive play-based art-related "movement" consisting of human computer confluence with responsive media offering societal contribution. Substantiating the arguments, the acknowledged movement\* ArtAbilitation® [including GameAbilitation®; TeleAbilitation®; Non-Formal Rehabilitation® & Ludic Engagement Designs for All (LEDA)®] has since been realized.



## **Abstract:**

This research explores sensor-based interactive systems to determine requirements for an untraditional tool to support therapeutic intervention and learning.

Rather than concentrating on a specific physical disability, focus is on a means to stimulate a participant's existing ability to articulate creatively and playfully. Through motivating interactions via empowering unfettered gesture control of responsive digital multimedia in recreational activities, e.g. video gaming, music making, painting, and robotics; a 'whole-person benefit' - including impairment - is targeted.

A bespoke infrared sensor-based system was the vehicle for the investigations. Examined variables include (a) participants across wide age ranges and spectrum of ability including profound multiple disabilities (PMD), cerebral palsy (CP), acquired brain injury (ABI), and typically developing (TD); (b) different test locations; and (c) contrasting sensor-based apparatus.

End-user access, inclusion, and participation in the 'recreation-as-training/learning' activities were augmented through using divergent mediums adapted to the participant's profile. Gain in concentration, eye-to-hand contact and other self/social skills were amongst the reported PMD and CP benefits. Potentials within ABI were also positively evaluated, especially balance, body dynamics, and independence training. Despite the brevity of the study, the use of video games in various hospital contexts was also positive.

Results, and the research overall, signify the promise from using unencumbered gesture control of multimedia in this context. Benefits from regular use are hypothesized ranging from specific healthcare intervention, across various training/learning situations, to generic life quality. External expert evaluations substantiate these claims.

Despite the positive evaluations, limitations were identified in all the tested apparatus. This supported the determining of the requirements towards an optimal system solution. Thus, irrespective of the resultant patented product, it is concluded that a need still exists for an improved turnkey solution.

SoundScapes thus evolved from being product-centred into an open research platform upon which further ongoing multi/inter-disciplinary explorations are conducted.

## **Acknowledgements**

Eva

The University of Sunderland supervisors, examiners and staff.

Participants, their families, research locations staff, co-authors and others who have contributed to my learning.

Dedicated to my mother Dulcie Joan Mary, and my father John Russell Brooks who passed away during the writing of this commentary.

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## Submitted Publications List: Articles are referenced by the roman numerals in the body text

- I. Brooks, T., Camurri, A., Canagarajah, N. and Hasselblad, S. (2002) 'Interaction with shapes and sounds as a therapy for special needs and rehabilitation', *International Conference on Disability, Virtual Reality and Associated Technologies*. Veszprém, Hungary, 18-20 September. Reading: Reading University Press, pp. 205-212.  
Available at: [http://www.icdvrat.rdg.ac.uk/2002/papers/2002\\_27.pdf](http://www.icdvrat.rdg.ac.uk/2002/papers/2002_27.pdf) (Accessed: 11 December 2005).
- II. Brooks, T. (2004) 'Robotic synchronized to human gesture as a virtual coach in (re)habilitation therapy', *International Workshop for Virtual Rehabilitation*. École Polytechnique Fédérale de Lausann, Lausanne, Switzerland, 16-17 September. Lausanne: École Polytechnique Fédérale de Lausann, pp. 17-26.  
Available at: <http://vbn.aau.dk/fbspretrieve/19908870/pdf> (Accessed: 22 December 2005).
- III. Lewis-Brooks. A. (2004) 'HUMANICS 1 – a feasibility study to create a home internet based telehealth product to supplement acquired brain injury therapy', *International Conference on Disability, Virtual Reality and Associated Technologies*. Oxford University, England, 20-22 September. Reading, UK: Reading University Press, pp. 43-50. Available at: [http://www.icdvrat.rdg.ac.uk/2004/papers/S02\\_N1\\_Brooks\\_Humanics\\_ICDV RAT2004.pdf](http://www.icdvrat.rdg.ac.uk/2004/papers/S02_N1_Brooks_Humanics_ICDV RAT2004.pdf) (Accessed: 21 December 2005).
- IV. Brooks, A.L. and Petersson, E. (2005) 'Play Therapy Utilizing the Sony EyeToy®', *International Workshop on Presence*. University College London (UCL), London, UK, 21-23 September. London: the International Society for Presence Research (ISPR) and Department of Computer Science, UCL, pp. 303-314. Available at: [http://www.temple.edu/ispr/prev\\_conferences/proceedings/2005/Brooks%20and%20Petersson.pdf](http://www.temple.edu/ispr/prev_conferences/proceedings/2005/Brooks%20and%20Petersson.pdf) (Accessed: 21 December 2005).
- V. Brooks, A.L. (2005) 'Enhanced gesture capture in virtual interactive space', *Digital Creativity*, 16(1), pp. 43-53.  
Available at: <http://www.informaworld.com/smpp/content~db=all~content=a714576431> (Accessed: 21 December 2005).

## **Submitted publications list: Notes**

The publications listed on the preceding page are selected to represent this research. They are published between 2002-2005. The list includes additional online links for public domain availability for the reader's reference. The page is in landscape format to ensure the links are listed without line breaks. The reference style is Harvard (author-date) style according to Pears, R. and Shields, G. (2005) *Cite them right: the essential referencing guide*. 2nd edn. Newcastle upon Tyne: Pear Tree Books.

The papers are summarised in chapter 7, with the published versions at the rear of the document. Other non-submitted publications are available at the author's University page: <http://personprofil.aau.dk/forskning/publikationer/103302>

# 1 Introduction

A need was identified for improved opportunities for disabled people to articulate creatively and playfully. Therapeutic, social, and quality of life benefits were conceptualised.

The idea was based upon developing an alternative means to supplement traditional therapeutic intervention through increased access and inclusion to recreation activities. The research sought to determine requirements for an optimal solution to address the need.

A bespoke ‘system’ enabling unfettered<sup>1</sup> gesture control of multimedia was created as a vehicle to explore the requirements for addressing the identified need. The intervention was based upon a whole-person methodology.

Examined variables included (a) participants across a wide age range and spectrum of ability including profound multiple disabilities (PMD), cerebral palsy (CP), acquired brain injury (ABI), and typically developing (TD); (b) test locations; and (c) sensor-based apparatus. Five publications are selected to exemplify the researching of use of the system across variables and its evolution.

The system is referred to as ‘SoundScapes’. International luminaries evaluated SoundScapes’ apparatus and methodology, as applied in the field, prior to commencement of the studies reported in the submitted publications. A published patent, a product, and international and nationally funded research projects resulted.

This opening chapter outlines the rationale and background of the research. It includes a section on body movement data, which is the prime system feedforward input. Chapter two highlights the related technologies and research. The prototype device and its enhancement are introduced in chapter three. Chapter four presents the various multimedia examined as feedback content with example images. Subsequently, the methods, the theories, and the emergent research models follow in chapter five. A designated chapter on the concept of Aesthetic Resonance follows and then chapter seven summaries the submitted publications, which are included in full at the rear of the

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<sup>1</sup> Unfettered is also referred to as unencumbered (see Krueger *et al.*, 1989)



commentary. Chapter eight closes the commentary by presenting discussions, the conclusions, and the future research. The next section introduces the background of the research.

## ***Background***

The SoundScapes rationale evolves from the author's personal experiences with profoundly disabled relatives. These experiences, together with a background in engineering, music and performance/installation art, are the primary motivating drivers behind the work.

A lack of means for individuals with profound physical dysfunction to articulate creatively and playfully beyond traditional apparatus and methods was identified. It was observed that impairment prevented, or severely hindered, their inclusion in recreation activities. This gap in the field was identified through interactions with disabled relatives and those in their communities. Determining the requirements for a solution to address such means are at the core of this research.

The preliminary applied research explored a bespoke touch-to-MIDI<sup>2</sup> interface (built in 1985), biofeedback systems, and others. Limitations were identified in all tested apparatus. This led to a bespoke infrared (IR) sensor-based, gesture-to-MIDI device being built in the early 1990s. The device enabled control data to be generated from a participant's unfettered movement. The term 'Virtual Interactive Space' (VIS) was coined to refer to the active zone that sources the participant's movement (Brooks, 1999).

Improvements to the prototype continued throughout the 1990s. The evolution of the prototypes and the ongoing testing of related technologies highlighted the potentials of sensor-based interactive systems as a means to address the need for a solution. Further research was undertaken to establish advantages, disadvantages and limitations to determine requirements of an optimal system.

The potentials of using the recreational interactions as a therapeutic tool to 'train' the means of expression, i.e. the movement itself, became apparent as the research progressed. However, it was not the purpose of the research to determine

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<sup>2</sup> Musical Instrument Digital Interface

human benefits from the system use. It was rather to determine the system requirements that could maximise the opportunities for access and inclusion toward such benefit.

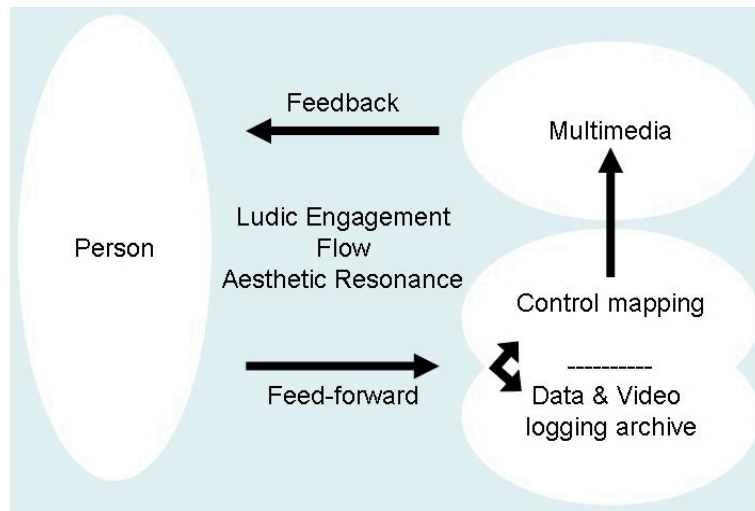
Testing of the bespoke prototypes in the field inductively evolved the whole-person approach that focused on abilities whilst addressing each participant's personal profile, including desires and preferences for interaction. Also, as the author is not a therapist, this was used rather than a traditional therapy treatment approach that focused on the person's impairment with specific and specialised 'training'. Nevertheless, throughout the history of the work many therapists, staff, and other healthcare experts have been involved. Their contributions are herein acknowledged, as this research could not have evolved without such insight and knowledgeable experiences that were shared. Staff inclusion was also to ensure participant comfort and appropriate assessment reports for institute leaders, family, and others.

### ***Body movement data***

Lyon, Sorensen, and Pipenbring (CRBI, 2004) point out the links between movement, motivation and emotion. The links relate to the principle behind the research concept i.e. the participant's initial body movement being mapped to manipulate selected feedback content. The resulting participant sensed stimulus motivates a reaction resulting in subsequent body movement that is sequential to the original/previous motion. The sequential movement, which is then responsible for sequential feedback content stimulus generation, is considered secondary whilst the original/previous motion is referred to as the primary movement. The closure of this afferent efferent neural feedback loop (article I), where control of the multimedia stimulus is the conscious focus, rather than the associated primary and secondary physical movements, is key. Motivating continued interest, and thus maintaining the loop closure through meaningful interactions, is referred to as the participant's 'ludic engagement' (e.g. Gaver *et al.* 2005). In this context, motivated ludic engagement results in Aesthetic Resonance (articles I-IV; Ellis 2004b; chapter 6).

Enjoyable, achievable, and fun challenges are presented for the participant to interact with via body movement. A goal is to achieve the participant's Aesthetic Resonance, ludic engagement, and flow (Csikszentmihalyi, 1991). Set-up variables include participant positioning relative to the sensor apparatus location and range of

participant movements. Adjustments to these variables, which are significant to body movement tracking and subsequent data generation, are fine-tuned as a session/program progresses alongside other input/output parameter adjustments. Over a series of sessions the variables and their adjustments are stored and then recalled for subsequent system refinement.



**Figure 1: Feed-forward/feedback data system: the conceptual framework.**

Figure 1 simply illustrates how a person/participant's primary movement within the volumetric VIS is sensed by the infrared 'interface'. The sensor-based device translates the movement into feed-forward MIDI data that is routed to a computer's usb<sup>3</sup> MIDI interface. Mapping of the streamed (in-action) data is via a software programme capable of archiving and processing to adaptive/scalable control of multimedia (e.g. MAX/MSP/Jitter<sup>4</sup>).

The multimedia acts as feedback stimulus that is sensed by the participant. Sequential/secondary movement is thus stimulated, which is sensed by the technology and the cycle continues iteratively. This causal participant/system, feed-forward/feedback sensorimotor interaction, achieves afferent efferent neural feedback loop closure as exemplified in the studies (articles I-V). Subsequent tailoring of the system is thus via the sensitising device parameters, the mapping parameters, or the multimedia parameters.

<sup>3</sup> Universal Serial Bus (USB) is a specification to establish communication between devices and a host controller (usually a personal computer)

<sup>4</sup> A family of interactive graphical dataflow programming environments for audio, video, and graphical processing sold by the company Cycling74.

The participant's movement interactions and responses to the empowered control are video recorded for correlation to the archived streamed movement control data. As visual feedback mediums are used, video recording of the multimedia that affects the participant is also archived synchronised to the video recordings of the participant interactions. The archived video is also suitable for post-session (on-action) movement data analysis (e.g. article IV). This set up assists in the complex process of evaluation of the system use.

The next sections present the research questions and targeted functions that determined the approach taken.

### ***Research questions***

Questions that were asked include:

- How can use of SoundScapes give participants an improved physical level of activity and function?
- What is the potential of SoundScapes to become a relevant and novel product as a supplement tool for therapeutic intervention?
- How can SoundScapes qualitative methodology contribute to and be compared with traditional therapy methods of quantitative evaluations?

### ***Targeted functions***

The controlled multimedia feedback had to cover three functions. It had to:

- Provide meaningful content to the user so as to enthuse and motivate further engagement.
- Facilitate data analysis for the research team at technical and behavioural levels.
- Provide therapists, families and carers with the possibility to monitor behavioural change.

These questions and functions are addressed throughout this commentary.

This opening chapter summarises the threads of the argument that have evolved from the background rationale. The next section presents the contextual/literature review where a focus is on the related sensing technologies and their use with disabled people.

## **2 Contextual/literature review**

Key to the SoundScapes concept is the ability to convert body movement into tangible expressive multimedia output to suit the participant's profile. Commonly used technologies, tested in this work, to facilitate this transformation are reviewed in this chapter. Related work in the field of disability is included.

### ***Ultrasonic sensors***

Invisible ultrasonic technology has a linear capture profile. Disadvantages include an annoying auditory clicking being emitted and, when used in arrays, sensor-to-sensor cross-interference resulting in false signalling. This can also occur from the signal bouncing off hard reflective surfaces. The examples below demonstrate the efficacy of ultrasound technology as a facilitator for training linear movement.

'SOUND=SPACE'<sup>i</sup> (Gehlhaar, 1991) is a proprietary system comprising a matrix of eight custom ultrasonic sensors where movement triggers topographical sound compositions. Originally conceived as a musical composition performance tool, disabled children first used 'SOUND=SPACE' in 1988.

The commercially available Soundbeam<sup>ii</sup> ultrasonic sensor device was originally created in 1984 for dancers to control musical accompaniment through their movements (Swingler, 1998; Carter, 2001). Noteworthy research within disability is Ellis' Sound Therapy work (e.g. 1994-2004b).

### ***Wearable biofeedback sensors***

Wearable biofeedback sensors provide an alternative to ultrasound technology as a means of transforming signals to tangible expressive output. In the examples, MIDI data is generated from dynamic body signals via wired sensors attached to the skin at specific locations. A disadvantage of this technology is that biosensors demand precise, uncomfortable, time-consuming placement of the sensors onto the body, usually with electrode gel to improve the signal. The wires attaching the sensors to the interface are encumbering. Also, signals are susceptible to noise and variance of lag time that varies according to sensed source. This is problematic in this context where

clean signals are required with minimum latency for a direct and immediate feedback stimulus to mirror body activity. The capability of wearable biofeedback sensors is illustrated by the following two systems that have been tested.

‘BioMuse’ (Putnam and Knapp, 1993) is an eight-channel sensing system conceived to control auditory feedback via the body’s bioelectric signals (e.g. Warner *et al.*, 1993). A more affordable four-channel sensing system is the Waverider (e.g. Allanson and Mariani, 1999).

### **Camera systems**

A third alternative, which avoids the interference problems associated with ultrasound technology, and also removes the need to have invasive sensors attached to the body is the use of cameras to detect movement (e.g. article IV). The movement is tracked in the camera’s field of view on a two-dimension plane perpendicular to the viewing angle, i.e. planar. A disadvantage of camera-based motion tracking systems is the need for stable controlled lighting. Infrared filters and specified lighting help to address this problem.

Rokeby’s (1986-1990) camera-based ‘Very Nervous System’<sup>iii</sup> (VNS) was conceived for a dancer’s movement to control his/her own musical accompaniment. Examples of use include musicians with quadriplegia (Trevitanus, De Kerckhove and Rokeby, 1993) and physically challenged children (Winkler, 1997).

Other camera-based systems include the Eyesweb<sup>iv</sup> software as used in article IV (see also Brooks and Hasselblad, 2004).

### **Laser technology**

Laser-based interfaces to control auditory feedback are increasingly being used in this context as an invisible switch to trigger single events e.g. ‘HumanBeams’ (Riopelle, 2003) and Laserweb (Coniglio, 2005). These systems are subject of limited author testing especially regarding safety with participants and eye impingement.

This chapter presents a selection of sensor-based technical systems originally conceived for performance art and the manipulation of solely auditory stimulus.

Associated works illustrate implementation with disabled participants. Contrasting this approach, the bespoke three-dimensional (3D) volumetric sensing prototypes originated specifically for the research as outlined herein, i.e. therapeutic intervention beyond a single modality of stimulus. The next chapter introduces the created apparatus, its evolution and enhancement.

### **3 SoundScapes**

This chapter introduces the bespoke apparatus, their use, and the philosophy behind the design and its evolution. The sensing enhancement technique that extends the Virtual Interactive Space (VIS) (Brooks, 1999) is then presented. Innovations within the context of SoundScapes, which seek to address the limitations of the technologies reviewed in the preceding chapter, are also highlighted.

#### ***The interface***

Building upon preliminary research, bespoke devices were created based upon invisible infrared light energy operating at a wavelength beyond human perception. The infrared volumetric sensing profile offers a viable alternative to the technologies reviewed in the preceding chapter that are limited to source linear or planar movement.

The device enables a participant's unfettered 3D movement to control multimedia without the need for strength or dexterity beyond a participant's residual physical capacity. The emitted light, when reflected, acts as a dynamic active space. The lack of a tangible interface gives a 'magical' intuitive quality for participants as only minimal gestures are needed to trigger digital events. The multimedia responses can be adapted and/or scaled by programming the sensor head and/or via the signal mapping. Unlike the tested ultrasound sensor devices, the infrared sensor does not emit sound that may distract end-users. Unlike the camera devices, the prototypes generally operate with stability of signal under variation of lighting, even in pitch black; though intense daylight reduces sensitivity. Because of this the studies were conducted in interior locations. The infrared sensors are safe to use unlike some lasers and can be programmed beyond acting as simple invisible switches.

Movement within the emitted IR influences the intensity of light reflected back to the sensor's photodiode receiver. The reflected light has a variable intensity proportional to the nearest point of movement within the active space. The generated MIDI data (i.e. control signals) correspond to the dynamic light intensity. A related



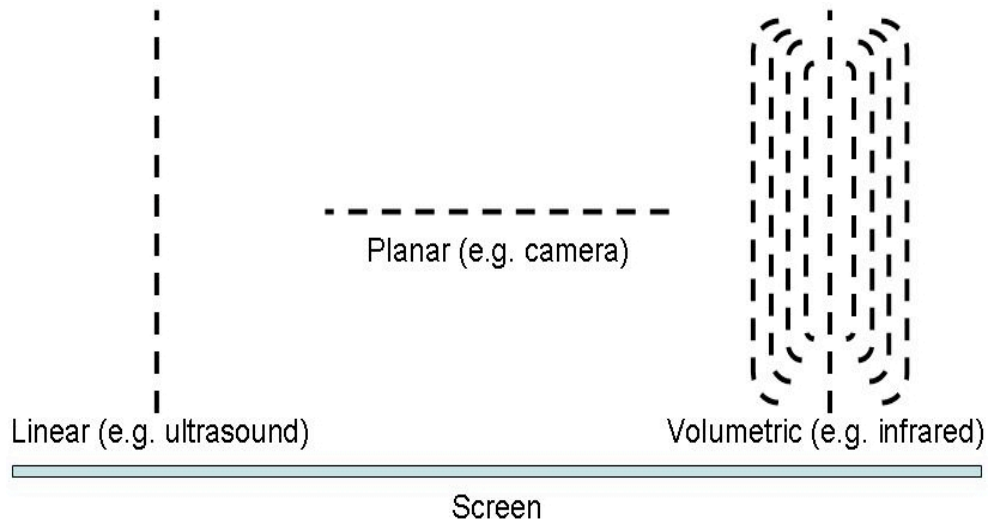
infrared guitar pedal replacement, ‘Dbeam’ (De Franco *et al.*, 1995; Hawken, 1997), was also tested for human movement control with positive outcome.

A disadvantage of the 3D infrared sensing profile is that, in operation, similar data can be generated via motion at any point around a central axis (figure 2). The resulting feedback can disorientate participants. Article V details this sensing profile.

### ***Movement data sourcing: linear, planar and volumetric***

SoundScapes is a very simple idea based on intuitive causality.

In line with Bærentsen’s (2000) ‘interface’ description, the bespoke apparatus movement sensing means, being invisible and volumetric, requires no prior knowledge or ability to operate. Similarly, Qvortrup’s (2001) interpretation of ‘interaction’ is in line with the VIS concept where the experience is of ‘entering the interface’ to operate, i.e. where the feedback itself acts as direct and immediate feedback to unfettered input. Figure 2 illustrates the sensing/operational profiles of linear/ultrasound, planar/camera and volumetric/infrared as used in articles I-V relative to the associated device positioned along a screen line. The 3D volumetric/infrared profile (illustrated as 2D in figure 2) highlights how data is located around a central axis, which can lead to participant disorientation.



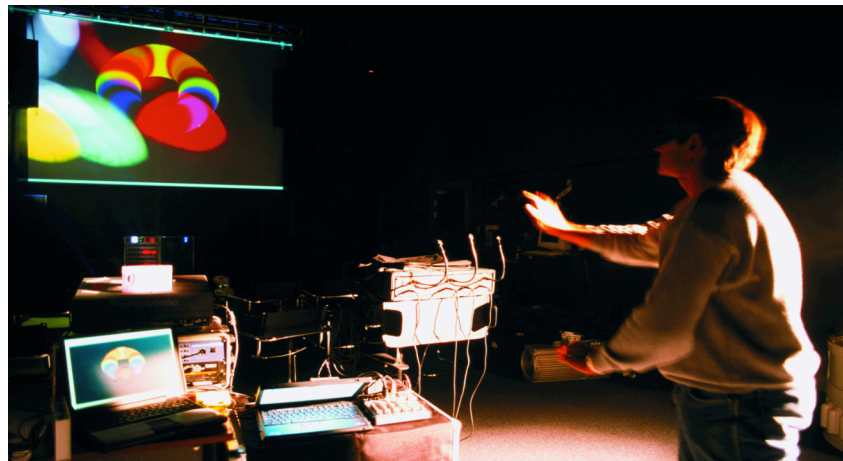
**Figure 2: Sensor movement data capture profiles: linear, planar and volumetric.**

## ***Prototypes***

The first bespoke infrared-sensor prototype was created as a single-headed unit. Subsequent devices were three-headed (figures 3 and 4). The increased number of sensor heads enabled independent multiple channel triggering (MIDI note on/off events) and control (MIDI control data). Examples are mappings to Red-Green-Blue filters for colour manipulation, animation parameters, robotic devices, and/or music instrument patches (Articles I-V). MIDI control data increases the sensitivity options for personalised influence. Figure 4 shows the prototype in action.



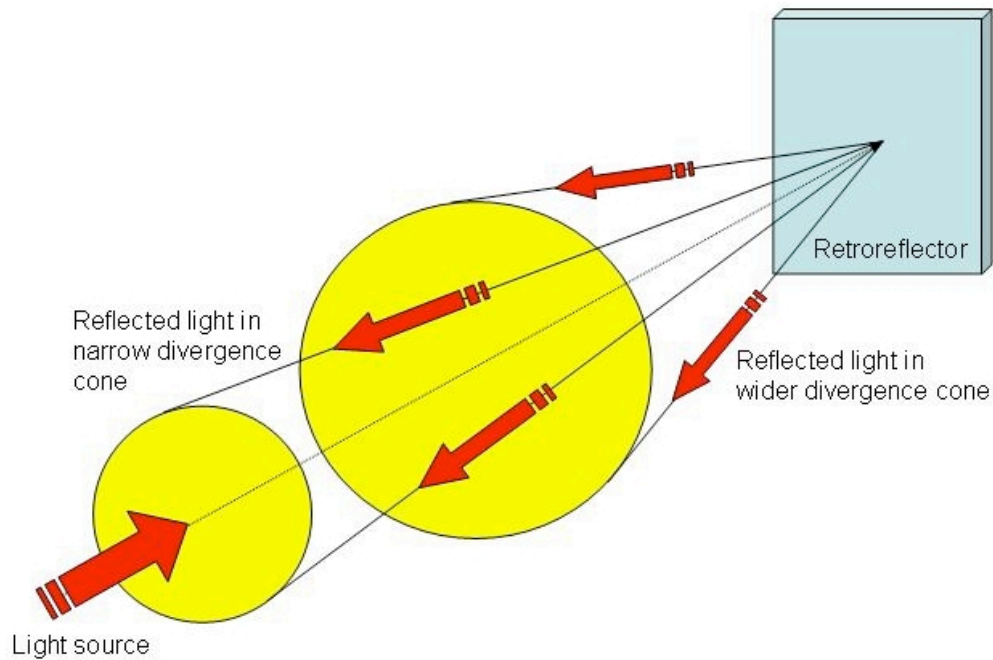
**Figure 3: Three-head prototypes (c. 1993 left and c. 1999 right<sup>v</sup>). The smaller sensor heads (on right prototype) are extendable via XLR cabling, which improves sensor location for operation (e.g. reaching over wheelchair arms/leg support), which augments user inclusion.**



**Figure 4: The three-headed prototype (1999) in action enabling gesture control of robotic lighting, audio, abstract image and colour blends.**

### ***Enhanced movement data collection***

The principle behind the infrared ‘enhancement technique’ is shown in figure 5. In this way, the Virtual Interactive Space (VIS) (Brooks, 1999) is extended beyond a volumetric 3D profile without the need for additional devices or markers on the body (see also article V).



**Figure 5: Exemplifying the principle of retroreflector enhancement (abridged CIE, 2001).**

The technique involves a large piece (e.g. 0.5m x 1m) of retroreflective material that is cut and mounted onto a window blind so the reflecting surface increases as the slats are manipulated from horizontal to vertical.

The material consists of highly effective retroreflective microprism cube-corner formations that reflect up to 250 percent more light than glass beads. Up to 70% of the sensor-emitted infrared energy is thus reflected back to its origin via the material's controlled divergence of the light rays (CIE, 2001; Reflexite, 2001). The bespoke apparatus' maximum (non-enhanced) 3D infrared sensing operational distance is around 150 cm. However, with the reflector this distance increases to over 12 meters and the 3D profile is enhanced to include a secondary 2D profile (article V).

### ***Occlusion technique for movement data collection***

Occlusion is the effect of one object in space blocking another object from view. In computer vision occlusion causes problems in the tracking motion of a human form. However, in the enhancement technique context, occlusion, in the form of the participant's dynamic body movement, is used to block reflected light from the

window blind to the sensor receiver. Balance, rotation and other qualities of gross body movement can thus be trained with multimedia feedback. For example, participants are able to close their eyes to focus on auditory feedback cues that amplify movement feedback. The amplified feedback enables the participant to achieve a sense of the movement that otherwise may not be available because of their impairment. In other words alternative channels of sensing is empowered by the prototype for fine and gross movement through either the 3D near field or enhanced 2D VIS respectively (e.g. article III and V).

### ***Beyond interaction***

In contrast with commercial ultrasound sensors, where adjacent sensor interference is problematic, the infrared 3D and enhanced 2D sensing spaces can be crosshatched without any false triggering providing there is no cross-sensor impingement (article I and II). An option of use is creation of an extremely high resolution VIS wherein exploration beyond conscious interaction and control is available. However, this is not elaborated further beyond defining it as a requirement for an optimal system.

In the preceding chapters, the argument for creating and using a bespoke infrared interface device that enables sourcing of gesture from within an invisible active sensing space (VIS) to control multimedia is outlined. This chapter illustrates the actual prototypes, its attributes, its use and enhancement.

The next section introduces the multimedia content that is manipulated by unfettered gesture within the VIS. The equipment used for delivering the audiovisual mediums is also presented.

## **4 SoundScapes multimedia feedback**

Building upon the preceding chapters where the bespoke prototypes, the explored variables, and the thread of arguments behind the cohesive thread of the work is outlined, this chapter introduces the various multimedia content that is mapped as feedback stimulus in articles I-V. The rationale behind the choices of the presentation equipment is also outlined.

### ***Presentation equipment***

Escaping the desktop to enhance the user experience, a LCD projector and large screen or white wall is used. A responsive ‘mirrored’ digital image approaching one-to-one scale was found to be optimal to promote the participant’s immersion and self-association to his/her own body movements in the VIS. This technique reflects how, in traditional proprioception training sessions, a physiotherapist uses a large mirror to train PMD participants in body awareness.

A stereo speaker system delivers auditory stimulus that mirrors the participant’s movement in the VIS. It was not readily apparent whether there was a participant response change when more than two speakers (left and right stereo) were used, e.g. surround sound 5:1 format.

### ***Multimedia Content***

A wide variety of multimedia has been tested to determine advantages, disadvantages and affect of the feedback content. Such content, as exemplified by articles I-V, is becoming increasingly available for mapping via unfettered gesture control.

The use of auditory stimulus in SoundScapes is more in line with Gehlhaar’s (1991) compositional approach than Ellis and van Leeuwen’s (2002) use of solely whole tone scales. Options include a microphone (with effects), digital samples (created or own sounds), and/or synthesiser patches. These are used to motivate and empower the participant to make ‘music’. Contemporary audio software offers a multitude of programming options for movement control, e.g. the automatic stepping

through a familiar melody sequence where each next event triggered by a gesture is automatically the correct note; sequential arpeggio manipulation; or more sophisticated processing such as affecting granular synthesis parameters. These challenges target cognitive and physical development. However, as stated earlier in this commentary, the cohesive thread of the work is system use rather than specific human outcomes. Thus, the specific programming is not elaborated beyond that posited in articles I-V.

Visuals are similarly explored for participant preference versus ability and level of challenge e.g. Virtual Reality; abstract animation; video games; robotics; and ‘body-painting’ (e.g. articles I-V). Figures 6-9 exemplify visual feedback with caption notes on setup and use. Mapping algorithms offering access to in-action parameter changes also increases the personalisation options (e.g. article II appendix). This supports the facilitator intervention decisions and is central to the emergent model ‘Zone of Optimised Motivation’ (ZOOM) (Brooks and Petersson, 2005). The following figures are extracts from the research illustrating the diversity of the content used.



**Figure 6: Gesture controlled dolphin game (c. 2000) e.g. where each sensor is mapped to control the dolphin’s horizontal travel and vertical travel. An example of use is where each sensor is controlled independently (e.g. ABI end user and facilitator/therapist) and subsequently together (participant only). The progression from one to two-sensor control indicates end user progress. Participants’ session-to-session competition with others in the study was motivated by numbers of fish eaten, the points scored, and the time listed on a chart (see Lewis-Brooks and Petersson 2005).**

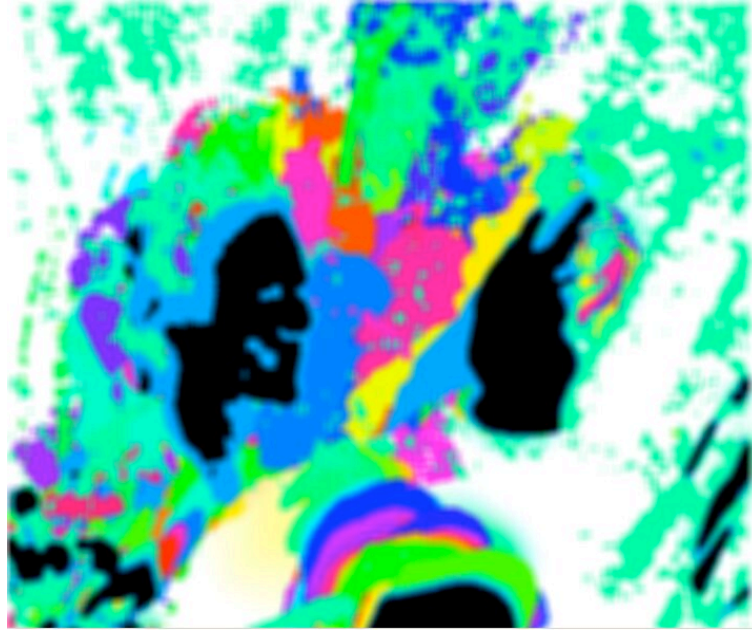


**Figure 7: Audiovisual mirroring via the Eyesweb Bodypaint Aesthetic Resonant Environment, c 2001 - where the dynamics of the tracked motions step through adjustable motion threshold levels of an algorithm to empower parameter change via self-selection. This means that a participant can self-change auditory or visual sequential stimulus by gesture. An example of use is for training control of motion dynamics where specific motivation goals are set e.g. challenging no colour change whilst ‘painting’ a border around the screen, or stepping through a known melody (Brooks and Hasselblad 2004).**



**Figure 8: PMD hand/head movements within an Eyesweb Bodypaint Aesthetic Resonant Environment. Using the same algorithm as exemplified in the previous figure, but adapted to the more severe limitations of the specific end user (see Brooks and Hasselblad 2004).**





**Figure 9: Carer and PMD participant in the Eyesweb Bodypaint Aesthetic Resonant Environment. On cessation of each session a printed screen shot tangibly signifies session achievement as e.g. a family gift or wall exhibit (see Brooks and Hasselblad 2004).**

This chapter exemplifies how the work has evolved through actively examining the ever-increasing opportunities for the manipulating of multimedia feedback content.

As pointed out in the preceding chapters, the use of the bespoke infrared interface to control diverse digital multimedia contrasted with other research that, at the time, controlled solely digital auditory stimulus (see chapter 2).

The next chapter presents the methods of inquiry and emergent models that have evolved from the on-action and in-action reflections (Schön, 1983; 1987).

## 5 Method of inquiry

According to Patton (1990) the qualitative strategy of inquiry is reflected by (i) the individual outcome; (ii) the desire for collecting detailed in-depth information about the phenomena under inquiry; (iii) the focus on the diversity and unique qualities of individuals; (iv) that there is no available standardized, valid, and reliable instruments. In line with this interpretation, a best fit to SoundScapes' determinants was deemed as a synthesis of the known qualitative approaches of Action Research and Hermeneutics.

Action Research is a methodology conducted from within the situation that is being studied toward change where it is acknowledged that the researcher can have an influence and bias (Kolb, 1984; Denzin and Lincoln, 2000; Kemmis and McTaggart, 2000).

Hermeneutics is an iterative strategy where knowledge and knowing is created from examining the relationship between the whole and the parts that are dependent on each other that together, through interpretation, create understanding (Schleiermacher, 1977; Gadamer, 1989; Alvesson and Sköldböck, 2000). This synthesised approach emphasises a recursive and reflective process to analyse the diverse triangulated data generated from the studies.

Methodological strategies in the field exhibit similarities and disparities. For example, Ellis' (2004b) grounded theory approach differs to Gehlhaar's (2005) 'explorative with pedagogical intent' approach.

In contrast, SoundScapes' approach is 'spiral and reflective' resulting in inductively emergent hybrid models for 'in-action' and 'on-action' reflections that are mutually informing under a social cultural activity theoretical framework (Vygotsk, 1978; Leont'ev, 1981; Wertsch 1981). For brevity and to maintain the focus on the apparatus exploration, the emergent models are not elaborated further in this commentary. The next chapter introduces Aesthetic Resonance by discussing how the various definitions reflect the context of application.

## 6 Aesthetic Resonance

The preceding chapters introduced the system and the methodologies of use and evaluation. This chapter discusses the concept of Aesthetic Resonance, which is a term used across various disciplines (table 1). Table 2 presents definitions from research with disabled people starting with ‘Aesthetic Resonance’ (Ellis, 1997, p. 175). This definition originated from working with children empowered to control sound through motion that resulted in their “aesthetic motivation” and “internal resonance” (Ellis, 1995, p. 77). The author’s text in table 2 differs by denoting the situation, i.e. the created installation, as an Aesthetic Resonant Environment (article I).

**Table 1: Examples of use of the term "Aesthetic Resonance"**

- in Sound Therapy for the profoundly disabled (Ellis 1997, 2004a)
- In rehabilitation with audiovisual stimulus (Camurri *et al.*, 2003; 2004)
- In Internet performance art (Broeckmann, 2004)
- In reflecting artist experiences (Hagman 2005a)
- In questioning music, creative process and self-experience (Hagman 2005b)
- In sculpture art (Collins, 2005)

**Table 2: Definitions specific to research with disabled participants**

- Ellis, 1997: *special moments experienced by individuals described as having profound and multiple learning difficulties, in which they achieve total control and expression in sound after a period of intense exploration, discovery and creation.*
- Brooks *et al.*, 2002: *a situation where the response to an intent is so immediate and aesthetically pleasing as to make one forget the physical movement (and often effort) involved in the conveying of the intention.*
- Camurri *et al.*, 2003: *an environment giving patients a visual and acoustic feedback depending on a qualitative analysis of their (full-body) movement, in order to evoke ludic aspects (and consequently introduce emotional-motivational elements).*
- Ellis, 2004a: *special moments when a child achieves real control and expression after a period of intense exploration, discovery and creation – moments which can be seen to be both ‘endearing’ and ‘touching’.*

Article I presents a study examining Aesthetic Resonance beyond solely auditory stimulus. A multimodal definition describing Aesthetic Resonance/Aesthetic Resonant Environments thus originated and evolved from the author-led European funded ‘future probe’ titled ‘Twi-aysi’<sup>vi</sup> (The World Is As You See It). Table 2 extract (labelled Brooks *et al.*, 2002) is from this definition.

Table 2 also presents a definition by the CARE HERE<sup>vii</sup> (Creating Aesthetically Resonant Environments for the Handicapped, Elderly and Rehabilitation) project consortium Italian academic partners. This definition clearly links to the earlier multimodal definition (article I). This claim is further substantiated by the fact that the Eyesweb bodypaint algorithm, as exemplified by figures 7-9, was author-originated (see also Brooks and Hasselblad, 2004; Camurri *et al.*, 2003). Ellis’ (2004a) subtle text reformulation in table 2 suggests acknowledgement of Aesthetic Resonance occurring beyond solely auditory feedback stimulus and beyond solely participants with profound and multiple learning difficulties.

‘Aesthetic’ derives from the Greek ‘aisthethai’, to ‘perceive’. In this research it refers to a participant’s external representation of what is internally perceived. The externalisation of the perceived experience is an intuitive response to the interactions. It signifies a ‘communication’, a linkage, to an innate ‘inner quality’ that has relationship to self-achievement, self-empowerment and self-agency. This complex communication is mediated by the interactive system and its affordances, as illustrated in the submitted articles (I-V).

In SoundScapes, ‘Resonance’ refers to the above-mentioned ‘inner quality’ resulting from the interactive system-mediated experience. This known quality of the motor system refers to how it responds during the observation of an action. This is where higher order motor action plans are coded so that an internal copying of the interactions is not repeated but is, rather, used as the basis for the next motivated action (Rizzolatti and Arbib, 1999).

The ‘observed action’ is not of a specific motor action. It is rather the observation of the reaction of the feedback content to the controlling motor action. Aesthetic Resonance is thus directly associated to afferent-efferent neural feedback loop closure (articles I-V), which is tentatively suggested as a reason why interactive multimedia is so effective with disabled people.

Evaluation of the use of the system (apparatus and method) is primarily via the participant's body movement/motivated actions alongside verbal utterances, facial expressions, and other non-verbal behaviour/communication (see patent detail in appendix 1).

These evaluation aspects are common between related works (e.g. Ellis and van Leeuwen, 2002; Ellis, 2004b; Gehlhaar, 1991; 2005).

The next chapter summarizes the selected publications, thus, narrating the progress of the author's studies within the framework of the questioned aims, method and context elaborated so far, and highlighting the contributions made.

## 7 Summaries of the Submitted Publications

This chapter summarises the publications selected to depict the evolution of the concept, apparatus and method that constitutes the coherent thread of the work. Public domain online links to the publications and the author's other work are listed on page ix. The full versions of the papers are at the rear of this commentary.

The publications exemplify the explorative investigations across the diversity of participants, the various system setups, and the different locations as presented in the preceding chapters.

**Article I** reports on a series of Danish and Swedish studies funded by the European Network of Excellence for Intelligent Information Interfaces<sup>viii</sup>. The probe was titled Twi-aysi (see the preceding chapter).

Explorative investigations were of apparatus and methodologies with PMD and CP children and teenagers. Contributions are acknowledged from teachers, parents, and carers (see figure 10, page 23). Vibroacoustics feedback was examined only in the Swedish study therefore it is not detailed further. A focus was the investigation of Aesthetic Resonance beyond solely auditory feedback.

Building on the author's prior research, the potentials of unfettered 3D gesture control of multimodal stimuli, especially visuals, from within a VIS environment was investigated to challenge the prior single modality definition of Aesthetic Resonance/Resonance (Ellis, 1997).

A main finding was that Aesthetic Resonance was clearly indicated across the range of stimuli beyond solely auditory, i.e. including visuals and robotic device control. This led to the multimodal/multimedia redefinition of Aesthetic Resonance/Aesthetic Resonant Environment (see the preceding chapter).

This study acknowledges the complexities innate of evaluating the human interactions. Interactions are monitored and video recorded through numerous cameras to maximise observable session data. This is coined Multiple Camera Analysis [MCA]

and is where the original session video recordings are archived in their entirety. This contrasts to Ellis' (1996) 'Layered Analysis' methodology where a single camera is used and master recordings are edited and recorded over, which results in only limited material being available for subsequent reanalysis. Thus, important instances, which may not be prevalent on first viewing, e.g. between session activities are therefore lost.

Exemplifying an outcome from this study is a video clip of a young PMD child controlling a spaceship through his head gesture<sup>5</sup>.



**Figure 10:** Setup for the Twi-aysi project with control of vibroacoustics (a Soundbox<sup>ix</sup> under participant), audio, and visuals (left wall): Sweden c. 2000. Mother, Carer and Teacher support.

**Article II** reports on the second of a series of original studies investigating unfettered gesture control of 'intelligent robotic lighting devices'<sup>x</sup>. The potential to motivate PMD children to move, play and creatively express to achieve Aesthetic Resonance was examined. This study involved four PMD male children between 3.5 and 5 years of age. The study built upon earlier research (c. 1993-4) investigating

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<sup>5</sup> <http://www.youtube.com/watch?v=m5-I9NHPt2I>

scanner lighting devices with the bespoke alpha prototype. The advanced control of physical attributes afforded by the more contemporary device enabled increased potentials for synchronous control, and thus stimulation, of the disabled children.

The children exhibited swift understanding, quickly realizing the physical-to-physical connection. The robotic devices became a new ‘toy’ to discover and explore. The children’s responses were focused, powerful and intense. Attending staff expressed satisfaction at what they observed relating how special it was for the children.

Afferent-efferent neural feedback loop closure, flow, ludic engagement, and aesthetic resonance were positively evaluated. However, the detailed sensor data analysis was problematic as the infrared “night shot” facility of the video recording camera impinged upon the infrared active sensing, thus interfering with the movement data capture. This was only discovered post publication.

The conclusions in this article failed to highlight how the video and staff indicated the significance of how the ‘creative’ play was evident from interactions. Similar potentials were evident in the earlier research with light scanners. The increased physicality of the robotic moving head units in this study was assessed as offering added reinforcement and scaffolding of self-awareness for the children of their own actions as posited by Bruner (1973). Specific related research has not been located to corroborate findings.

This study relates to article I through its exploration of the gesture control of audiovisuals within the field of disability. Also, the same four children were tested in both studies in the unfamiliar location of a Danish university laboratory.

The findings are corroborated by the author’s other studies by how aesthetic resonance is achievable irrespective of medium; auditory, visual, or robotic, providing there is a sufficient curiosity and interest in the content. The study also relates to article III where the same robotic devices were used.



**Article III** reports on an investigation with five adult ABI participants (patients) that resulted from investigations between 1997 and 2000 where the author researched SoundScapes at numerous hospitals.

The study reports on the first phase of the ‘HUMANICS’ project at the Centre for Rehabilitation of Brain Injury<sup>xi</sup> (CRBI) in Copenhagen. CRBI is a leading organisation specializing in meeting the neuropsychological, linguistic and physical challenges resulting from ABI.

The overall aims of this project were to first establish the potentials in ABI i.e. this study building on the previous work that had met with positive assessments. Then, if positively evaluated by the government appointed experts and CRBI internal staff, to develop a product that was suitable for healthcare professionals to establish programmes for ABI home activities/training. The author’s global project design focused upon advancing the bespoke interface device and VIS to use the Internet as a communication tool for monitoring and reporting patient progress from self-managed home training. Another goal was participant-to-participant increased home and online social interactions, e.g. in competitive play and collaborative creation. This is presented within the patent (appendix 1) and illustrated in the article (figure 1: Humanics telehealth system).

In line with the articles (I and II), infrared and ultrasound sensors were explored controlling audio, visuals and robotic devices. The article also presents how the study examined the sensor enhancement/occlusion technique (see page12-13 herein; article V). The technique was used with auditory feedback so that stroke participants could train whilst listening to their body movements. Gesture control of animations and robotic lighting devices was also used with hands and hidden footswitches to train hand/foot coordination and control. A formal protocol battery of tests (psychological and physiological) was created from this first study for the follow-on study (CRBI, 2004; Lewis-Brooks and Petersson, 2005). A criticism of this study is the inability of the physiotherapist to escape a formal approach focusing on traditional treatment of impairments. This is reflected in the outcome protocol, which fails to

realise the potentials of the technology to supplement traditional test batteries with alternative (possibly more precise) measures.

Neuropsychologists, physiotherapists and psychologists conducted the expert evaluations, which led to the follow-on project (Lewis-Brooks and Petersson, 2005). Evaluations gave special mention to the originality in using gesture controlled interactive multimedia in ABI training where a focus was on motivated creativity and play, as at the time there was no specific related research literature found.

The sensor enhancement technique was especially effective for balance and article V gives more details on this concept. Appendix 4 illustrates the CRBI distributed research brochure along with a letter from the director substantiating the author's role in the research.

**Article IV** reports on an explorative study to advance the author's earlier investigations of alternative gesture control of video games via VIS (Brooks, 1999).

This study furthered the investigations of gesture control of interactive multimedia as a supplemental tool for use within healthcare and rehabilitation as reported in articles I, II and III. In this case a camera-based sensor that enabled gesture control of a commercial video game was explored.

Third party facilitators, i.e. doctors and therapists, conducted the sessions according to the author's design to research the healthcare industry adoption potentials from their perspective.

Eighteen TD youngsters attending hospital outpatient departments participated in the study. The video game was tested with an imposed restriction of a single level of challenge. The research goals were wide and explorative.

The enquiries questioned presence (e.g. Riva *et al.*, 2003), the advantages and disadvantages of camera-based sensing, Video games control as therapeutic intervention, and computer-supported analysis. In this way the studies reported in the articles (I-III) are extended through explorations of (a) sensing technology (chapter 2),

(b) multimedia content (chapter 4), (c) participants, (d) evaluation approach (chapter 5), and (e) locations.

The game was appropriate and the camera interface enabled direct and effective interaction with the game environment. External factors, such as movements behind the participants or lighting changes, introduced problems by corrupting the interactions. As presented in chapter 2, this is a common problem that is improved when the computer software algorithms enable increased control of artefact activation within the field of view.

All the children exhibited high levels of engagement, and their motivation to play was evident. However, after achieving their high score, some of the higher skilled participants made it clear they desired increased levels of challenge. As this was not open for them to advance, their motivation diminished.

The computer-supported analyses techniques functioned successfully but were limited and necessitate further work. Improved interpretations would likely result from additional specialists collaborating to assist video decoding of the meanings and their relevance for the participant and therapist goals from interactions. The setup had to be dismantled and re-established, as the test location was a multifunctional room. This could have corrupted data analysis through movement of apparatus, however, it did not influence in this study.

Conclusions drawn from this study were of evidence of the afferent-efferent neural feedback loop closure, achieved participant flow and ludic engagement. The association of Aesthetic Resonance to presence was assessed through the participant's game-induced motivated actions. The doctors and play therapists that conducted the studies; the children; the staff; and the parents were all positive about the use of video games in this healthcare context.

It was evident that videogame systems have substantial and divergent potentials in hospital settings; in this case staff, parents and participants reflected upon how day-care waiting room use could alleviate boredom as well as promote exercise.

For camera-based gesture control to be widely adopted, designated rooms are required so that control of the environment is optimised and consistent. Findings suggest how gesture control of video games will open up new opportunities in healthcare as well as across mainstream and ‘specialised’ educations.

**Article V** is an invited journal article developed from two of the author’s papers presented at the international conference for Computers in Art and Design Education (Palmer, 2005). It differs from the preceding articles (I-IV) by having more of a focus on reporting specific qualities of the bespoke interface, especially its enhancement and technique of use. Comparisons are made between the other technologies used in articles I-IV, specifically the commercial Soundbeam ultrasound device (chapter 2).

Despite the wide use of infrared cameras in motion tracking systems, finding related literature on specific use of 3D volumetric infrared technology as a controller of an interactive multimedia system for use in healthcare and rehabilitation was problematic. Also lacking in the literature was how the retroreflection technique enhanced potentials for the infrared interface by offering two distinct profiles within one device.

Describing the enhancement is the main focus of the article to determine whether the combination was novel to consider for the targeted eventual product.

Examples of use are included in the closure of the article. This is seen as a fitting final selection to close the selected articles section as divergent applications are collected that indicates the relationship and progression of the studies.

In this way, the five selected articles, and this commentary, exemplify the core thread of explorations across technologies, participants and location, to contribute to the field by defining what is required for an optimal interactive system to address the identified gap in this specific field.

## **Overview**

Overall, the explorative studies exemplify what is basically a simple exercise of empowerment. Positive evaluations of concept and system use were received from across the variety of ‘experts’ and end-users. Alongside the assessment of concept and system use are the complexities inherent in evaluating the human behaviour issues conducted by the appointed experts. This input from experts strengthens the evaluation of the system use and thus influences its evolution.

An overall critique of the submitted research articles (I-V) might suggest a weakness through the lack of a recognized systematic effect analysis alongside a stringent traditional single methodology.

Defending the approach and strategy taken, contextual ethical regulations dictate that all evaluations are as methodical and rigorous as possible. Thus, throughout the research the author’s activities and observations have been undertaken within the bounds of such ethical regulations, as monitored by healthcare experts, staff and families. This was systematically investigated by exploring use across variables to define requirements for an optimal interactive system for this specific context.

Rather than a weakness, this is considered as highlighting the originality of the work. This is pertinent especially when the period when the work originated is taken into account.

The speculation of originality, contribution, and impact is substantiated through e.g. the patent titled ‘Communication Method and Apparatus’ (appendix 1); the international reviews (appendix 2); the physiotherapist report extracts (appendix 3); and the CRBI material (appendix 4). These are further elaborated in the research conclusions in chapter 8.

**Table 3: Selected user-centred studies - an overview.**

Publication	I	II	III	IV
REFERENCE	ICDVRAT 2002	IWVR 2004	ICDVRAT 2004	Presence 2005
Input tech	Infrared + Ultrasound	Infrared + Ultrasound	Infrared + Ultrasound	Camera
Enhanced VIS	x	o	x	o
MIDI	x	x	x	o
Image animation	x	x	x	x
Audio	x	x	x	x
Robotic	x	x	x	o
Video game	o	o	o	x
Virtual Reality	x	o	o	x
IMPAIRMENT				
Profound (PMD)	x	x	x	o
Acquired brain injured (ABI)	o	o	x	Y
Typically developed	o	o	o	x
ANALYSIS				
MCA (video)	x	x	x	x
Interviews	xZ	Z	xZ	xZ
Questionnaire	o	o	o	xZ
LOCATIONS	School + Lab	Laboratory	Clinic	Hospital (2)

For ease of cross-reference, Table 3 presents a simplified overview of the submitted user-study articles (I-IV); ‘x’ denotes inclusion; ‘o’ denotes not included; ‘Y’ mild impairment through oxygen problem at birth; ‘Z’ denotes significant other (parent, doctor, or friend) and not impaired end-user; and xZ denotes end-users and significant other. Article V is not considered as a user study and therefore is not included in the table.

The next chapter presents the conclusions of the commentary.

## 8 Conclusions

This research explored unfettered gesture control of multimedia. The cohesive thread throughout the work was to investigate interactive systems and the requirements for an optimal solution to address the identified need for augmenting creative and playful articulation of people with impairment. A goal was to augment access and inclusion in recreational activities that could offer participants increased opportunities for social and other quality of life benefits. The potentials of an untraditional therapeutic tool were examined via a bespoke apparatus and an open-ended whole person method that inductively evolved throughout the applied research. The examined variables included participants across a wide age range and spectrum of ability. Locations, both familiar and unfamiliar, and comparisons between apparatus and methods were also examined.

The preceding chapter summarises the five publications (articles I-V) selected to exemplify the research. The triangulated data (e.g. test results, interviews, and video evaluations) from the studies are ‘thick descriptions’ in Danish; thus, they are not included in this commentary. However, additional material to substantiate the commentary text is included as follows: -

- Appendix 1 presents the patent that evolved from the research.
- Appendix 2 exemplifies evaluations of the bespoke prototype system and its use via reviews and letters, these include from (i) a senior lecturer from the University of Bristol, UK, who was the technical research partner in the CARESS project<sup>xii</sup> that investigated Aesthetic Resonance; (ii) a USA healthcare industry expert<sup>xiii</sup> who visited Denmark especially to review the applied work. The visit was following her (creative arts therapist) sister<sup>xiv</sup> experiencing SoundScapes at a 1999 presentation in New York<sup>6</sup>; (iii) the Executive Director of the USA Biofeedback Society of New York<sup>xv</sup>, who also attended the same New

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<sup>6</sup> <http://www.integrativemedicine.org/library/aimconf99form.html> and <http://www.integrativemedicine.org/library/conf2.gif>

York event, and (iv) the head of industrial relations, Danish National Centre for IT Research, Denmark. This Danish text is from The Centre for Advanced Visualization and Interaction (CAVI<sup>xvi</sup>) where the studies from articles I and II were conducted.

- Appendix 3 is a personal communication supplied by one of the physiotherapists that worked with SoundScapes with PMD and CP participants. Her evaluation of participant outcomes is listed. A series of 3rd party video<sup>7</sup> interviews substantiate these reported outcomes.
- Appendix 4 presents material from the ABI research that links to article III. The author's role in the Danish Government research that funded the published patent is stated.

These appendixes illustrate how the research contrasts other work, especially via the bespoke apparatus specifically created to explore therapeutic intervention and stimulus beyond solely auditory stimulus.

## ***Discussion***

The research examined the following issues:

- The use of SoundScapes and how it can give participants an improved physical level of activity and function?
- The potential of SoundScapes and what was needed for it to become a relevant and novel product as a supplement tool for therapeutic intervention?
- How SoundScapes qualitative methodology could contribute and compare to traditional therapy methods of quantitative evaluations?

To examine these points the prototypes were setup with a goal of:

- Providing meaningful content to the user so as to enthuse and motivate further engagement.

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<sup>7</sup> <http://www.youtube.com/user/sherman56#p/u/7/mxOV39MFzPw>



- Facilitating data analysis for the research team at technical and behavioural levels.
- Providing therapists, families and carers with possibilities to monitor behavioural change.

The prototype system use was assessed as offering increased opportunities for participants to take part in activities that train an improved physical level of activity and function. The benefits were apparent for the majority of cases but not all participants became engaged. It was not clear what differentiated the engagement. The PMD, CP and outpatient children sessions suggested a ‘mindset of play’ where the whole-person approach was readily achievable. Contrasting this, the ABI participants displayed a specific ‘therapy mindset’. Reflections are that pre-project communications (CRBI, 2004) influenced patient/staff expectations as the therapy mindset (vs. play) tended to diminish the engagement with the focus on impairment. This was especially prevalent in the follow-on study (Lewis-Brooks and Petersson, 2005).

Benefits were reported apparent for only a short time after the sessions, suggesting that a regular regime with the system was needed for transfer to a participant’s actual daily living (ADL).

When asking how SoundScapes qualitative methodology can contribute and compare to traditional therapy methods of quantitative evaluations one must consider the context and the idiosyncratic differences of the end-users. Qualitative evaluations in this field are complex and susceptible to bias, influences and misinterpretations. Article IV illustrates an experimental computer-assisted methodology offering both quantitative and qualitative motion-data. Thus, a mixed-method triangulation approach has evolved to contribute and to compare against traditional methods in this field.

The technique of mirroring a participant’s movement by ‘reflected’ digital mediums enable an alternative self-association to the participant’s motion sense (intentional or unintentional) and awareness of the limb involved in the movement (proprioception). In other words, what the brain may be ‘challenged to sense’ because

of damage or impairment can be offered through a system-mediated sense-substitution which fits into the causal afferent-efferent neural feedback loop that is normally closed within those people who are without damage or impairment. Thus, the usual psychophysical channels of sensed association of movement are offered alternative routings to supplement training of the sensing via multimedia feedback.

## **Motivation**

The focus of this section is the author's reflection on the 'designing for motivation' issues to determine requirements for an optimal solution.

Questioning system use and participant responses in line with achievements, it was found that the bespoke system motivated a feeling of "a need to do something" in line with Mahoney (1991). Such intrinsic motivation is defined as the motivation to engage in an activity primarily for its own sake rather than for an external reward. It usually results from the individual perceiving the activity as interesting, involving, satisfying or personally challenging; it is marked by a focus on the challenge and the enjoyment (Sternberg and Lubart, 1999).

According to Law *et al.*, (2001) a participant is intrinsically motivated when play is considered so that activity is for its own sake. This associates with 'Autotelic' activities that are engaged in purely for enjoyment (Steels, 2004). Correlation is to the emergent ZOOM (Zone of Optimised Motivation) model (Brooks and Petersson, 2005) wherein the concepts of Flow (Csikszentmihalyi, 1991), Zone of Proximal Development (Vygotsky, 1978), and 'in-action' reflection (Schön, 1983; 1987) conspire to motivate a vehicle upon which facilitator intervention can be queried in the context of an interactive environment and a participant with impairment.

Flow is where motivated play is considered according to (a) what the participant does, (b) why a specific activity is enjoyed, (c) how play activities are approached, (d) the participant's capacity for play, and (e) if there is relative supportiveness from the environment (Csikszentmihalyi, 1991).

Extrinsic motivation on the other hand is defined as the motivation to engage in an activity primarily in order to meet some external goal, such as attaining an expected reward, winning a competition, or meeting some requirement; it is marked by focus on external reward, external recognition, and external direction of one's work (Amabile, 1996; Runco and Chand, 1995; Torrance, 1995). This form of motivation is not excluded in SoundScapes as achievement within sessions can be represented in a tangible form and given to the participant – e.g. a print out of a digital painting through movement, a recorded music composition, and/or a video of interactions. However, whilst the research has shown positive outcomes from such an approach further studies are needed to validate the value of such tangible outcomes. In SoundScapes, it is primarily a participant's intrinsic motivation that is targeted via 'in-action' session activities.

### ***Healthcare industry adoption***

For interactive technical systems' apparatus and methods to be adopted within healthcare it is necessary to explore staff responses beyond evaluation of observed use. In other words, it was important that staff tried the systems.

The study reported in article IV was designed to explore staff use of a gesture controlled game system. Building upon previous work, i.e. a four-institute commissioned SoundScapes room from 1999; this study was conducted at two hospitals in Denmark and Sweden.

The previous work involved extensive author training of staff with regular evaluations and retraining. Contrasting this, the video game study required minimal introduction and training lasting half a day. The video game offered improved interaction and image quality.

Contrasting the prototype system, the video game system offered a turnkey solution enabling easier setup and operation. The potential adoption of gesture control of video games into therapeutic settings is considered high mostly because of this ease of use and high motivational content of selecting games that are of interest to play.

Contemporary games are affordable and, due to the size of the market, subject of rapid advancement through intense industrial competition that is suggested not as strong in the healthcare, therapeutic, or assistive technology fields. Alongside this, the advances in control peripherals (also called perceptual interfaces) improve accessibility and inclusion, thus offering an attractive alternative means for non-formal therapeutic intervention, exercise/training, and learning. However, games are also limiting by not permitting access to the data.

The commercial ultrasound system Soundbeam, which was examined by the author in a number of the studies, is commonly used in professional therapeutic situations. Whilst the system has been made to facilitate ease of use by staff, evidence indicates that, generally, use is limited to a basic level of note on/off interactions. Substantiating this claim is that the company offers additional training in the system use, e.g. at residential weekends.

Improvements in the user-friendliness of device operation for staff are considered a significant outcome of the work and a defined requirement of an optimal product.

Research findings highlight how costly investments, such as the Soundbeam, were discarded through lack of understanding of potentials of use, staff disinterest, or lack of time allotted to training. For example, because it uses the standard MIDI protocol (as used in the bespoke prototypes), the Soundbeam, in addition to the auditory feedback it was conceived to manipulate, can be used for linear gesture control of e.g. video games, animations, films, and virtual reality. Yet, not many of the institutes were aware of these opportunities.

To simply ‘operate’ such systems in their standard configuration is considered limiting the opportunities for the end-users.

SoundScapes research with bespoke diverse setups demonstrated how change and novelty is used to evoke and maintain motivation and engagement.

The research further indicated that the infrastructure is not in place to support healthcare personnel to fully explore such systems. Thus, funded collaborations with digital artists and/or additional training may be a solution.

The mapping of movement data to specific manipulations such that meaningful ‘control’ of feedback is achieved continues to be a challenge. A problem with some systems is a calibrations tailored to TD participants. In other words, problems arise from expectations of what ‘control’ constitutes as meaningful for the participant alongside an expectation of a participant that is capable of standing for calibration, which is not always the case in this context.

Based upon findings from this research, it is suggested that an optimal ‘total system solution’, will include integrated motion sensors and processors matched to onboard software that enable flexible calibration to various end-user profiles, alongside user-friendly configuration, ease of parameter change, and recall of adaptive presets. The defined optimal system requirements include the means to calibrate, track and programme the participant’s unfettered motion as well as to define the surrounding environment with responsive mediums. Such a system will accelerate adoption and proliferate emergent advances for applications in the healthcare field. However, currently, to the author’s knowledge, such a system does not exist.

Recognised impact and contribution is exemplified by: - SoundScapes being awarded the top prize at the 1999 EUREKA European Brokerage Event on Applied Multimedia (BAM)<sup>xvii</sup> and The Danish ‘Vanførefonden’ Research Prize<sup>xviii</sup>. This claim is substantiated by considering that the European (Twi-aysi and CARE HERE) projects; the Danish Government funded projects (Humanics 1 and 2), the published international patent (and related family of patents – see appendix 1); and a commercial product and company (Personics, 2004) all evolved from the work. Numerous international conferences papers and journal articles, academic citations of the work, and roles e.g. invited coordination board member of the European network for intelligent information interfaces (i3net); reside alongside invited talks worldwide and conference chair roles also indicate evidence of the recognised contribution.

A main contribution to knowledge of this work is the informing of how interactive systems can be used to contribute in supplementing traditional therapeutic and rehabilitation intervention by stimulating afferent-efferent neural feedback loop closure.

The work succeeds in offering a societal significance by intertwining “human, societal and technological elements into one dynamic research activity” (Wejchert, 2004, p. vi) that through its inherent user-centeredness and action potential gives added value and new opportunities to people with severe disability.

As stated previously, valuation of the specific benefits for end-users is not the purpose of this commentary. However, the possibilities for participants can clearly be observed without one being a therapist. These possibilities relate to how positive emotions result from creative and playful activities that greatly help with improving motivation, mood and life quality aspects during rehabilitation (Radtke, 1994).

The core argument inquired if disabled people are given an opportunity to express themselves creatively and playfully through residual movement whilst having fun with increased social interactions, then would they be more motivated to participate in activities that could be beneficial to their wellbeing? Outcomes indicate evidence of this. Thus, in practise, the intervention focused on creating situations where residual abilities are the human means for initial articulation.

Following the interactions motivating flow, ludic engagement and aesthetic resonance, a participant’s impairment is introduced to articulate alongside, or independent of, the initial ‘ability means’. This process is improvised and personalised to each participant. In this way, the mediating technology that empowered participation in the activity is considered an alternative means to engage the participant (and facilitator/therapist) in therapeutic training/exercise sessions. Further, as interactions were observed to motivate the participant to push their physical limits, without conscious engagement to the actual effort, then increased potentials for psychophysical development are tentatively speculated.

Requirements have been determined to suggest what may constitute an optimal system. Such a solution is currently not available. Thus, arrays of mediums, both feedforward apparatus/technology and feedback content, are constantly mixed and matched to develop interlinked input and output ‘libraries’. The libraries, which are forever increasing via technological advances, are used to create hybrid setups according to the participants’ profile and the training/learning goal of the session. Evolution is also evident via the increased multi/inter-disciplinary collaborations towards realising such a turnkey solution. The research is ongoing.

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## **Appendixes section**

## Appendix 1: Patent publication and family

Brooks, A.L. and Sorensen, C.D. 2006. *Communication Method and Apparatus*. DE60115876D D1.

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Brooks, A.L. and Sorensen, C.D. 2001. *Communication Method and Apparatus*. WO 0186406 A1

Filed 5th May 2000 (see following pages). Each patent family document above reflects the author's sole research/invention. Sorensen was CEO of the Personics Company. Under 'other publications' in the original document (Available at: <http://www.boliven.com/patent/US6893407>) the sole authored work as cited by examiner is extracted hereunder: -

1. "Bridging Cultures", Program from The 13th International Congress of WCPT, May 23-28, 1999, Yokohama, Japan.
2. "Pushing the Limits" Congress Program and Abstract Book, 5th Scientific Congress, Sydney 2000 Paralympic Games, Oct. 11-13, 2000, Sydney, Australia.
3. Letter from Clifford Madsen of the American Music Therapy Association.
4. Program and Letter from the Integrative Medicine Expressive Therapies International Symposium, May 26-28, 1999, New York.





(12) **United States Patent**  
**Brooks et al.**

(10) **Patent No.:** **US 6,893,407 B1**  
(45) **Date of Patent:** **May 17, 2005**

(54) **COMMUNICATION METHOD AND APPARATUS**

(75) Inventors: **Anthony Brooks**, Aarhus (DK);  
**Christopher Sorensen**, Grenaa (DK)

(73) Assignee: **Personics A/S**, Abyhøj (DK)

(\*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **09/565,924**

(22) Filed: **May 5, 2000**

(51) **Int. Cl.**<sup>7</sup> ..... **A61B 5/103**; A61B 5/117

(52) **U.S. Cl.** ..... **600/595**; 600/300; 600/545;  
600/546

(58) **Field of Search** ..... 600/544–547,  
600/300–301, 595; 345/156–168; 704/260,  
704/270, 271, 277

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\* cited by examiner

*Primary Examiner*—Robert L. Nasser

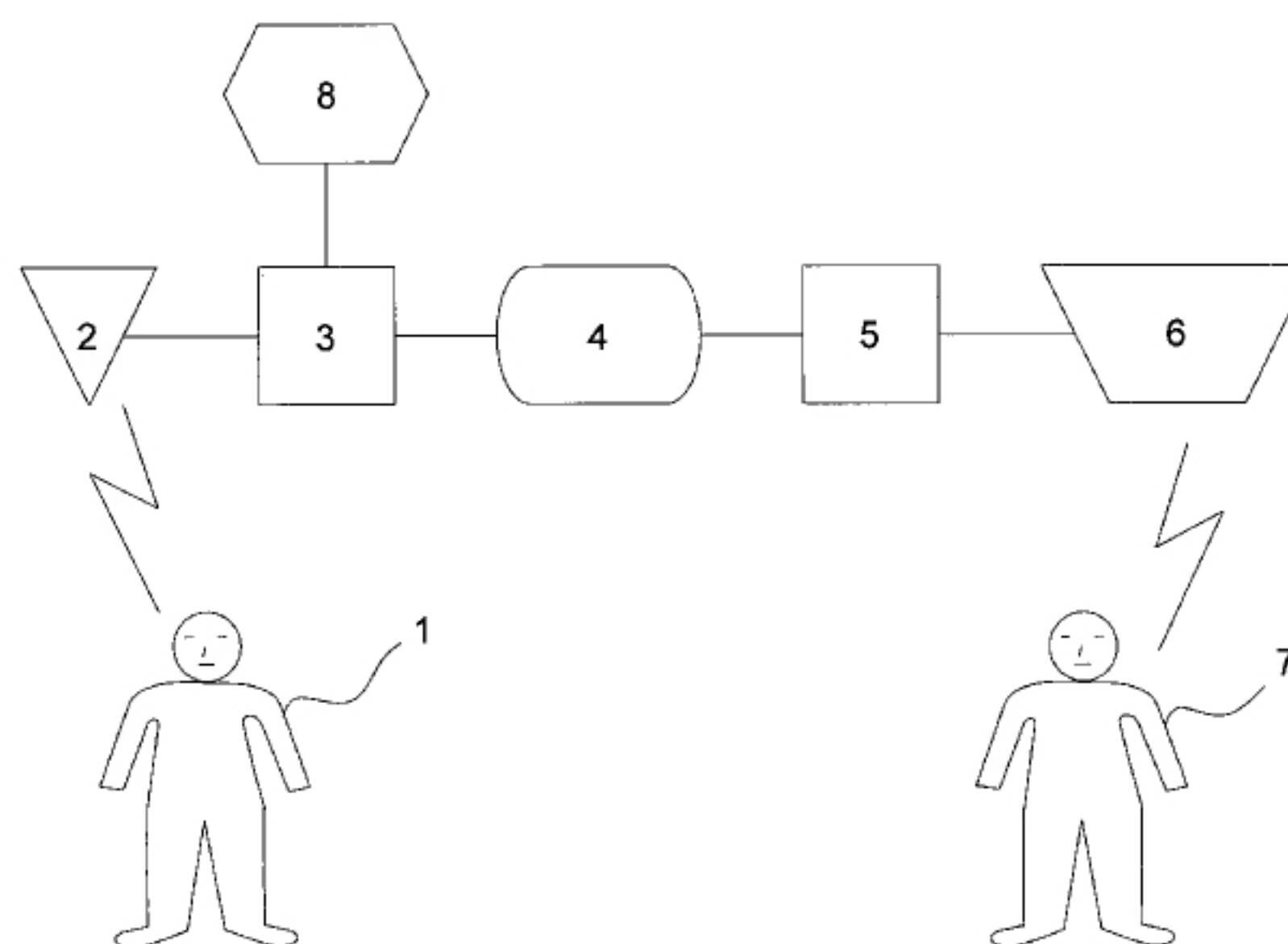
*Assistant Examiner*—Patricia Mallari

(74) *Attorney, Agent, or Firm*—Ladas & Parry LLP

(57) **ABSTRACT**

The present invention relates to a non-lingual communication method and apparatus, wherein a physical or physiological signal consciously created by a first subject (1) is detected and converted into a transmitted output signal presented to a second subject (7) in order to communicate information from the first subject (1) to the second subject (7). The invention further relates to rehabilitation of handicapped people.

**9 Claims, 2 Drawing Sheets**



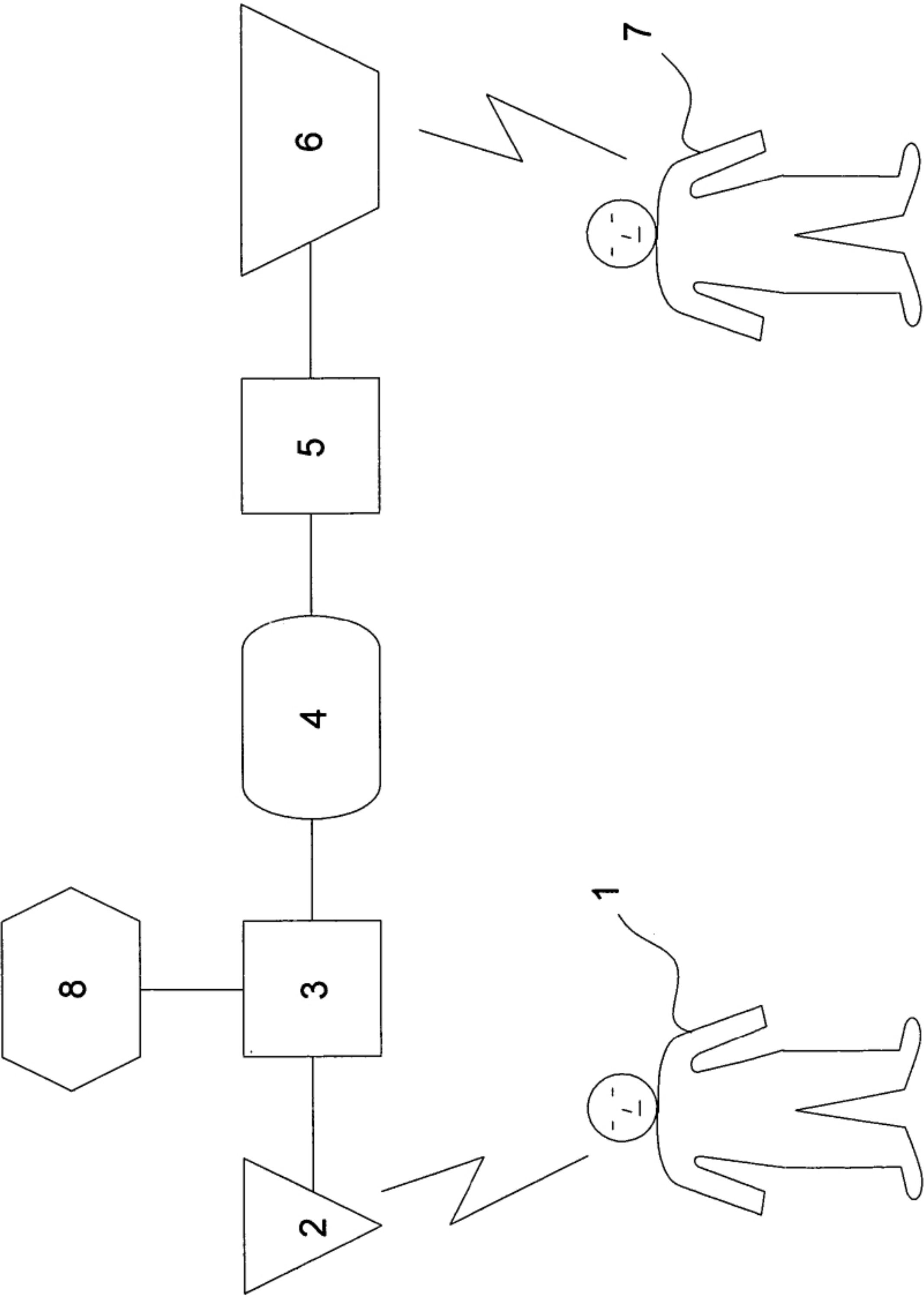


Fig. 1

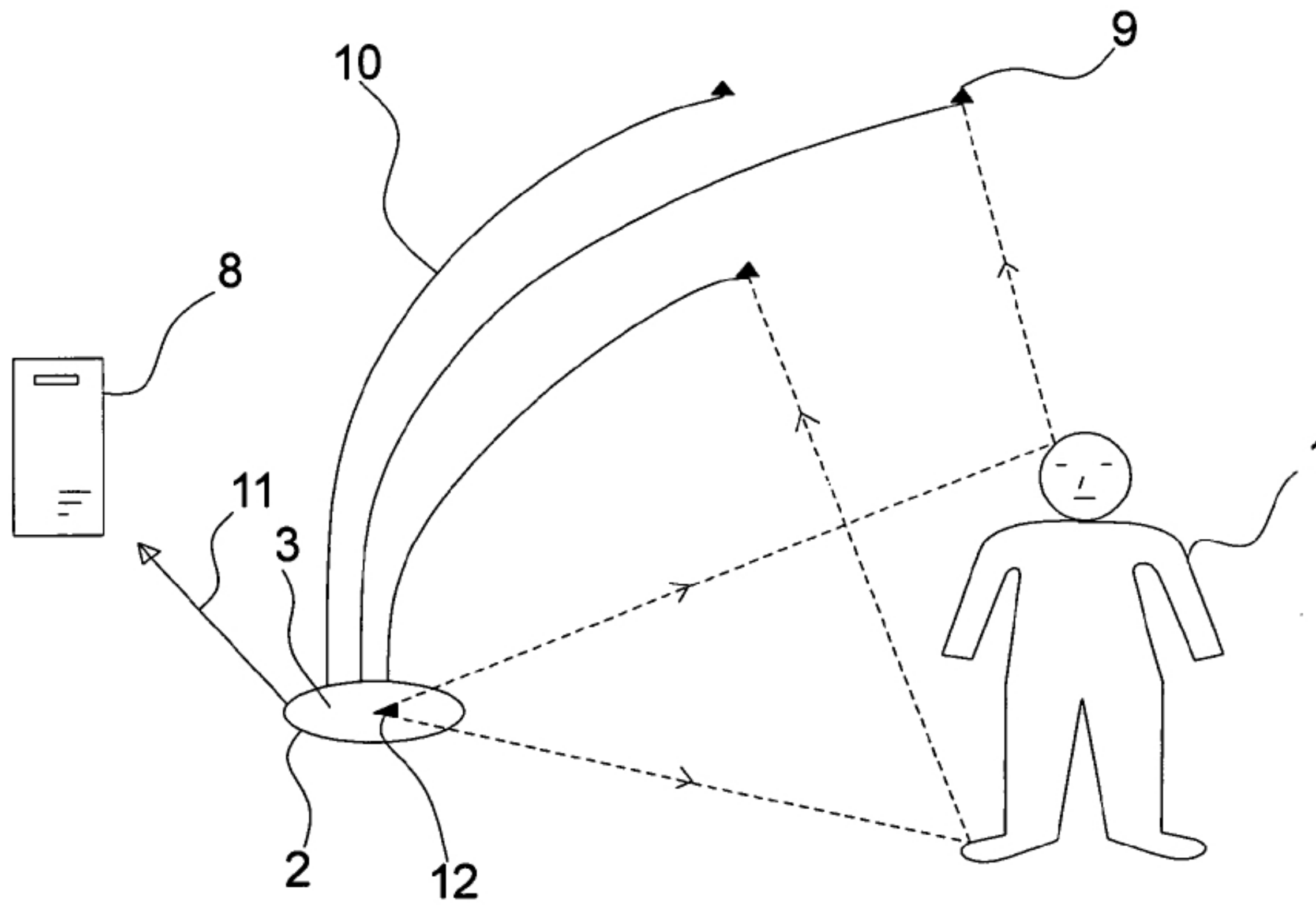


Fig. 2



COMMUNICATION METHOD AND  
APPARATUS

## FIELD OF THE INVENTION

The present invention relates to a non-lingual communication method and apparatus, wherein a physical or physiological signal consciously created by a first subject is detected and converted into a transmitted output signal presented to a second subject in order to communicate information from the first subject to the second subject. The invention further relates to rehabilitation of handicapped or otherwise disabled people.

## BACKGROUND OF THE INVENTION

It is well-known to use physical signals like movement of the whole body, for example by dancing, for electronic conversion into audio-visual signals. For example, U.S. Pat. No. 5,045,687 discloses an optical instrument capable of registering a person's movement in a defined space and converting the registered movement into musical tones and images. Also, measurement of physiological quantities as electromyographic (EMG) signals, galvanic skin response (GSR), electroencephalographic (EEG) signals, skin temperature, blood pressure, and heart rhythm (electrocardiography or ECG) have been used in biofeedback methods, where the subject is presented for a converted output signal indicative of the actual physiological state of the subject. Thereupon, the subject is able to change the output signal, for instance an audio-visual signal, as a response to a change in the physiological state. U.S. Pat. No. 5,662,117 discloses such a method and apparatus wherein the method is used to teach a person to relax even in a stressful situation. German Pat. No. DE 197 45 508 discloses a method and system where bio-electrical signals are converted to audio-visual signals presented for two persons that are competing in attaining the most relaxed state. U.S. Pat. No. 6,001,065 discloses a method and apparatus, where bio-electrical signals from a subject as a person, an animal, or a plant are used to control and interact with electronic media such as motion pictures, video games, virtual environments or security systems.

Though the prior art teaches measurements of physiological signals and conversion of these signals into an audio-visual signal, none of these references describes the use of physiological signals as a substitute for lingual communication between people. However, such a system would be a desirable tool for handicapped people who are unable to speak or to form words from letters as well as others who prefer non-verbal communication.

## OBJECTS AND ADVANTAGES

It is an object of the invention to provide a method and an apparatus for non-lingual communication between people. Non-lingual in this context is to be understood as an exclusion of spoken or written words.

It is a further object of the invention to provide a method and apparatus wherein a subject's physical and physiological signals of different nature are detected by a detecting medium and converted into a variety of different output signals to be presented to a different subject in order to communicate information from one subject to another.

It is a further object of the invention to provide a method and apparatus wherein the sensitivity of the detecting medium is adjustable according to a predetermined map or

is adjustable in an interactive process through an interactively learning computer including a neural network.

## SUMMARY OF THE INVENTION

A method according to the invention comprising a number of steps, wherein the first step is selecting an input medium and an output medium from a group of selectable input and output media having electronic means.

A number of detection methods are available to sense physical or physiological signals or parameters. If the parameter to measure is movements of the subject, for example movement of the body or a limb, it is possible to register this movement by an arrangement where an emitted wave after reflection at the body or limb is detected by a suitable detector. The emitted wave is for example for example an electromagnetic wave like laser light, a sound wave, or an ultrasonic wave. Movements alter the conditions for the reflection, and the change of the amplitude and phase of the reflected wave can be related to the movement of the body or limb. Examples of applicable electromagnetic waves are infrared light and visible light including laser light.

If movements of the body are to be detected, another possible arrangement including a so-called dance-suit can be employed. The dance-suit is equipped with detectors that change signal upon bending of joints like elbow and knees.

Further, a number of physiological signals are measurable. An example is temperature of the skin of the subject's body, breath pressure, oximetry (measurement of oxygen content in the subject's blood), or tremor. Other examples are electrophysiological parameters as brain wave activity (encephalography or EEG), heart rhythm (electrocardiography or ECG), galvanic skin response (GSR), skin conductance (SC), or muscle tension (electromyography or EMG).

As an output media, a large number of possibilities exist. Traditionally, sound generators and image displays are most common. However, other media would be desirable as well, especially if the invention relates to rehabilitation of those handicapped people that are not able to see and hear. Other possible media are vibration generators, heating devices, and electrodes that directly excite certain nerves. Also possible as input and output devices are mechanical controllers for wheelchair movements.

A second step in the method is detecting by said input medium physical or physiological signals consciously created by a first subject indicative of information to be submitted to a second subject, wherein the term 'second subject' is to be understood generally and includes also a group of subjects.

Generally, in biofeedback processes according to prior art, an audio-visual signal changes in response to the change of the physiological condition of the subject. The altering of the audio-visual signal guides indicates to the subject, whether a progress towards a desired physiological state is attained. Thus, information is submitted to the subject as a feedback to learn to control physiological parameters.

The aim of the invention is different and takes a step beyond prior art. According to the invention, the change of the subject's physiological parameters themselves are used to express information. Thus, a handicapped who is not able to move or talk, may be able to learn to control some of his physiological parameters in such a way that they can be used for communication. It might even be possible that subjects with equal or with different handicaps learn to communicate with each other using different physiological parameters for



expressing information to be communicated. In this light, the invention is a non-lingual communication method opening the possibility for severely handicapped people to communicate to the outside world in a way which has not been possible hitherto.

Once the signal from the subject has been sensed, for example an electrophysiological signal, this signal is converted to a transmittable signal. Usually, the detected electrophysiological signal is an analogue signal. In order to facilitate transmission of that signal, it is converted to a transmittable analogue signal or, preferably, a digital signal.

The format of the digital signal is compact to reduce the amount of data to be transmitted for thereby to increase the data transmission speed.

A fourth step is transmitting said transmittable signal, preferably digital data, to a data transformer, which is functionally connected to said output media. Digital data can be submitted without loss throughout the world by telephone lines, mobile telephone communication systems, broadcasting networks, or by the Internet, which is advantageous. A large and still increasing amount of the world's population has got access to the Internet, making this transmitter means a versatile tool for the communication related to this invention.

A fifth step is transforming said data to a sequence of output signals from said output media. The transmittable signal, preferably digital data, are after transmission transformed into a suitable format and transmitted to the output medium or media. How the transmittable signal is transformed is completely independent of the input media and only dependent on the output media. Different media require different formats. However, using digital data as the transmittable signal, where the format of the digital data itself is known, a transformer can be designed according to every special output medium.

A sixth step is presenting to said second subject said sequence of output signals for communicating said information from said first subject to said second subject. The output medium can be different to the input medium so that there is no limitation with respect to the form in which the signals are sent and received. For instance, it might be possible that the first subject communicates by GSR while the second subject receives this information from a heating device on the skin. On the other hand, the second subject might as an answer respond with an EEG signal which after conversion is received by the first subject as a vibration.

According to another embodiment of the invention, the method comprises calibration of the sensitivity of said input medium to correspond to a specific amplitude range for said physical or physiological signal wherein the calibration is performed according to a predetermined map, eventually including fuzzy logic.

The calibration may alternatively be performed by the first subject or the second subject, for example by interactive changing of the map. Electronic tools for this map may be stored in a computer or may be downloaded from the Internet. Not only the signalling from the first subject to and from the second subject is comprised in the non-lingual communication method according to the invention, but also the technical configuration including the calibration may be part of the communication, enabling the first and the second subject to optimise the system to the best possible communication form.

Detecting signals from the first subject may involve the problem to be solved in which the actual information is hidden in a minor part of the signal. Spastic movement of a handicapped person's limb may give a signal with a rather

large amplitude. However, the actual information from the handicapped person may lie in a more sophisticated pattern of movements overlaying the spastic movement. Thus, the actual information would in this case be an overlay signal on top of the signal with the large amplitude. In this situation, it is necessary to teach the detector to filter the actual information from the non informative part of the signal. In other words, a calibration has to be performed in a more or less sophisticated way. How this calibration is made depends on a map, which can be predetermined according to known factors including thresholds or range comparisons or more sophisticated methods including complex logical algorithms and a plurality of control parameters.

According to another embodiment of the invention, the calibration is performed by an interactively learning computer including a neural network. Though learning computers, where neural networks are included, are scarcely used today, the fast development of computers will give access to this kind of tool within short time. Using this kind of computer in connection with the invention open a new way of calibration. Any man-made map is dependent on the person who initially programmed the map or the routines for the map creation. However, in case a learning computer is used in connection with the detection of the subject's signals, the computer may after some time of learning during the interaction with the subject find out the optimum calibration itself through the interaction with the subject. This may or may not involve a rather long time for the learning process of the computer, however, a computer in contrast to a third person is not limited by a decreasing enthusiasm due to missing results at first stage.

There are subjects that are handicapped in a way which basically excludes them from communication with other people. Through history there have been reported handicapped people that have been regarded as having almost no substantial brain function, while those people at a later stage recovered partly from their handicap and could communicate to the outside world that they in fact experienced their surrounding all the time but just were physically unable to communicate. By learning to utilise control over physiological parameters, this kind of handicapped people may even learn to program and interact with a learning computer through their own kind of information signals, whereby the learning computer can be used as an interface between the subject and the outside world.

In the widest range of applications, the invention can be utilised to form a communication bridge between subjects of different kind. A completely new kind of communication may be possible not only between human beings but also between animals, plants and humans. The learning process may be a long lasting experimental period, however, with help by learning computers including neural networks combined with the creative skills from humans, the time to learn this new way of communication will be substantially shorter than the time it took for human beings to create the first written language.

Though the invention aims at constituting a communication tool for different kind of subjects, preferably handicapped people in rehabilitation processes, the invention can be used in a wider sense for a number of other purposes as well. Thus, the invention also is usable as a playing tool, for example creation of audio-visual sequences by an input of physical or physiological signals. The invention is further applicable as a feedback mechanism for a person training his skills to control and change physical factors or physiological parameters. Furthermore, the invention may be an intermediate link between a subject and an apparatus, where the

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apparatus is controlled through physical or physiological signals. These applications are known from prior art in a very limited form. However, the versatility of the present invention allows a much wider range of physical or physiological aspects to be interrelated with a great variety of different output media.

The invention also embraces a non-lingual communication apparatus comprising an input medium and an output medium selected from a range of selectable input and output media having electronic means, said input medium operable to detect physical or physiological signals consciously created by a first subject indicative of information to be submitted to a second subject, a converter for converting said signals into a transmittable signal, preferably digital data, a transmitter for transmitting said transmittable signal, preferably digital data, from said converter to a data transformer which is functionally connected to said output medium, said data transformer transforming said transmittable signal, preferably digital data, into control commands for said output media, wherein said output medium generates sequence of output signals for communicating said information from said first subject to said second subject.

In a further embodiment of the invention the apparatus further comprises calibration means for calibration of the sensitivity of said input medium to correspond to a specific amplitude range for said physical or physiological signal wherein said calibration is performed according to a predetermined map or by an interactively learning computer including neural network.

Though the primary object of the invention is a non-lingual communication method and tool between subjects, the invention may also be used for

- distant therapy, where a clinician is able to instruct and monitor a patient through a communication link, as for example the Internet or wireless communications links, in this case, the invention may be combined with a camera to monitor changes and improvements during therapy,
- body language and personal interaction training, for example of corporate leaders or of schoolchildren in a pedagogic environment,
- spectator interactivity whereas the participants in an event can interact with the performers and/or other participants locally or at a distance,
- theatrical movement, where dance or musical actions are transmitted to another group locally or at a distance, for example through television,
- personal entertainment or recreation, whereas a subject or subjects can, for example through the Internet, interact with others through a user interface or game
- controlling hardware, where the detected signal is used with a suitable transformer to control technical and/or electronic commands for the control of an apparatus.

#### BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 shows the invention in a schematic way,

FIG. 2 shows a set of detectors comprised by an input medium used to detect movements.

#### DESCRIPTION OF PREFERRED EMBODIMENT

FIG. 1 describes the communication apparatus in a schematic way. An input medium 2 detects physical or physiological signals from a first subject 1. These signals are converted into digital data in a converter 3. The converter 3 is coupled to a computer 8, where the signals are analysed

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and evaluated. Digital data containing information of the signal from the first subject 1 are transmitted by a transmitter 4 to a transformer 5 coupled to an output medium 6. The digital data are transformed suitably by that transformer that the output medium 6 can present a signal to the second subject 7.

The input medium can be one or more detectors of like or different kind, for example a detector that detects movement of a limb or of the whole subject 1. The output medium can be one or more specific media, for example a sound generator. Thus, movements of a limb from the first subject 1 is transformed into a sound pattern, as for example music, to be presented to the second subject 7.

The first subject 1 could for example be a handicapped person and the second subject 7 could be a therapist or another handicapped person, family member or friend. The terms 'first subjects' and 'second subject' are to be understood generally in that the terms also cover groups of people or even animals or plants. The invention enables the first subject 1 to communicate with another subject 7 in a way that is adapted to his skills. The invention can be used both ways in that a likewise communication link is established from the second subject 7 to the first subject 1.

Once a signal from the first subject 1 is detected, the conversion of the signal into digital data in the converter 3 is controlled by a computer 8. The converter and the computer may be separate units, but may also be combined into one unit. The control may preferably include a calibration of the input medium 2 such that the signal of interest is detected in the most appropriate way.

FIG. 2 shows an infrared, or alternatively ultrasound, emitter 12 and detectors 9, preferably on goose neck mounts 10, which facilitates adjustment of the detectors according to the moving part of the first subject 1, for example an eye lid. Using infrared light as detecting radiation has the advantage that background light does not disturb the signal, as this can be filtered from the detected signal. By limiting the emission and detection of the radiation to a defined bandwidth, also background radiation in the infrared regime can be reduced in order to prevent informationless contributions to the information signal.

The emitter 12 and detectors 9 comprised by the input medium are preferred but not limited to the type as described by DeFranco et al. in U.S. Pat. No. 5,475,214. Infra-red light is emitted by the emitter 12, scattered by the first subject 1 and then detected by the detectors 9. In the detection of limbs moved by the first subject 1, the scattered signal from the limb is enhanced, if the limb is provided with a reflective cover layer, as for example described by Walter in U.S. Pat. No. 5,171,624 and by Nilsen in U.S. Pat. No. 5,780,140.

Only one detector is necessary for the invention, however, the number of detectors 9 is variable. For example, three detectors 9 can be used to detect the signal. These three detectors 9 can then be used to control the red, green and blue components of a colour synthesised image, for example. Alternatively, the three detectors 9 may control three different output instruments to form music. If more detectors 9 are used, further elements can be controlled like graphic shapes or rhythm. Each detector can be assigned to whichever parameter is required to control.

Opposite the detectors, the goose neck mounts 9 are preferably equipped with 3 pin XLR connectors to allow for multiple extension if necessary. However, the invention is not limited to this kind of mounts.

Once the infrared signal is detected, it is transferred to the converter, where the analogue signal is converted into digital data. The input signal is, for instance, an electric signal with



a voltage between 0 and 5 V. This signal may be converted into to a digital signal with a range of 64 bit to ensure high dynamics. In the case of a sound generator as the output medium 6, the digital data alternatively may be of MIDI (Musical Instrument Digital Interface) kind. Spastic movement of a handicapped person's limb may give a signal with a rather large amplitude. However, the actual information from the handicapped person may lie in a more sophisticated pattern of movements overlaying the spastic movement. Thus, the actual information would in this case be an overlay signal on top of the signal with the large amplitude. In this situation, it is necessary to teach the detector to filter the actual information from the non informative part of the signal. In other words, a calibration has to be performed in a more or less sophisticated way.

In the most simple arrangement, this calibration may be performed manually. Alternatively, this calibration may be done in the computer after the signal conversion such that only a certain part of the full signal is transmitted to the transformer and used for communication to the second subject. However, the computer may control the calibration at the detector as well. The sensitivity of the detector may be adjusted to filter out parts of the signal. These calibration processes may be accomplished by predetermined algorithms according to a map.

However, the calibration may also be a process, where a computer is used which comprise neural networks and which is able to learn characteristics from the first subject 1 during the signalling process. These characteristics may be discovered by the computer by including intelligent frequency and amplitude analyses. For example, characteristics may be manifested by a changing frequency pattern with small amplitude on top of a rather large signal with a more or less constant or only slowly changing frequency. Using intelligent filters including Fourier analysis, the actual communicative information in the signal can be filtered from the total signal, even though the largest amplitude of the signal belongs to the non-informative part of the signal.

Between the converter 3 and the computer 8 data are transferred by a wired link or by a wireless data link 11, for example a telephone connection or a Bluetooth link. Between the converter and the transformer, the transmission may be accomplished by a variety of wired or wireless links including for example a telephone link, a television link, or the Internet.

The transformer 5 transforms the transmitted signal into a format suitable for the output medium 6, for example a sound generator. By this embodiment of the invention, the movement from the first subject 1 is transformed into a sound pattern presented to a second subject 6. In principle, the sound pattern may be presented to the first subject as a feed-back tool, eventually simultaneously with the presentation to the second subject 6.

What is claimed is:

1. A non-lingual communication method comprising the steps of:

- selecting at least one input medium from a group of selectable input media and at least one output medium from a group of selectable output media,
- detecting by said at least one input medium physical signals consciously created by a first subject indicative of intentional information to be submitted to a second subject,
- converting said signals into a transmittable signal,
- transmitting said transmittable signal into a data transformer, which is functionally connected to said at least one output medium,

transforming said transmittable signal to a sequence of output signals to be outputted from said at least one output medium,

presenting to said second subject said sequence of output signals for communicating said intentional information from said first subject to said second subject,

and calibrating the sensitivity of said at least one input medium to correspond to a specific amplitude range for said physical signals wherein said calibration step is performed according to a predetermined map;

wherein said at least one input medium is selected from the group consisting of

- an electromagnetic radiation emitter and an electromagnetic radiation detector for detecting movements,
- a sound wave emitter and a reflected sound wave detector for detecting movements,
- a laser scanner and a light detector for detecting movements,
- means for motion detection;

and said at least one output medium is selected from the group consisting of

- a sound generator,
- an image display,
- a vibration generator,
- a light pulse emitter,
- a heating device,
- a nerve exciting electrode, and
- a motor driven device.

2. The method of claim 1 wherein said transmittable signal comprises digital data.

3. The method of claim 1 wherein at least one of first and second subjects is a handicapped person.

4. The method of claim 1 wherein the input medium physical signals further comprise movements.

5. The method of claim 1 wherein said calibrating step is performed by an interactively learning computer including a neural network.

6. A non-lingual communication apparatus comprising:

at least one input medium and at least one output medium selected from a group of selectable input and output media, said at least one input medium operable to detect physical signals consciously created by a first subject indicative of intentional information to be submitted to a second subject,

a converter for converting said signals into a transmittable signal,

a transmitter for transmitting said transmittable signal from said converter to a data transformer which is functionally connected to said at least one output medium, said data transformer transforming said transmittable signal into control commands for said at least one output medium, wherein said at least one output medium generates a sequence of output signals for communicating said intentional information from said first subject to said second subject, and

calibration means for calibration of the sensitivity of said at least one input medium to correspond to a specific amplitude range for said physical signals wherein said calibration is performed according to a predetermined map;

wherein said at least one input medium is selected from the group consisting of

- an electromagnetic radiation emitter and an electromagnetic radiation detector for detecting movements,
- a sound wave emitter and a reflected sound wave detector for detecting movements,

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a laser scanner and a light detector for detecting move-  
ments, and  
means for motion detection;  
and said at least one output medium is selected from the  
group consisting of  
a sound generator,  
an image display,  
a vibration generator,  
a light pulse emitter,  
a heating device,  
a nerve exciting electrode, and  
a motor driven device.

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7. The apparatus of claim 6 further comprising calibration  
means for calibration of the sensitivity of said at least one  
input medium to correspond to a specific amplitude range  
for said physical signals, wherein said calibration is per-  
formed by an interactively learning computer including  
neural network.

8. The apparatus of claim 6 wherein said transmittable  
signal comprises digital data.

9. The apparatus of claim 6 wherein the input medium  
physical signals further comprise movements.

\* \* \* \* \*



## Appendix 2: SoundScapes\* reviews

\*In the following reviews the text "SoundScapes" was changed to "Personics" by the authors at the request of the Personics Company CEO.



19 JAN 2001

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Senior Lecturer in Digital Signal Processing*

12/1/2001

To Whom It May Concern:

We have been asked to comment on the technical and rehabilitation newsworthiness of the Personics concept and product based on our experience within the CARESS project including our use of Soundbeam.

We are the technical research partners involved in the CARESS project, which was successfully completed in June last year. As part of this project we used Soundbeam sensors and developed new wearable sensors. The project revealed to us that many improvements could be made and new ideas could be followed-up with the appropriate technology. In our wide search of commercial products and prototypes to support these, we became aware of the Personics system. This culminated in a visit to Aarhus on January 4th to trial the Personics prototype and to investigate the potential for a follow-on project, CARESS II.

The overall concept, sensors and modular software approach impressed us immensely. Amongst the benefits we saw for us, compared to the Soundbeam and sensors developed in the CARESS project, are:

- The Personics non-wearable sensors can achieve the same functionality as our wearable sensors developed in the CARESS project. This is significant since the non-wearable approach overcomes the limitations we were beginning to feel with our wearable sensors.
- The main limitations we found with Soundbeam is its inability to capture more than one-dimension and the inability to use several sensors together in a 3D space due to interference. These limitations came to the fore as we began to deal with more complex gestures expressed by the children as the project progressed.
- CARESS was restricted to the use of sound. Towards the end of the project, the Personics concept of audio-visual integration enthused us to investigate the use of visual material in our context. The EU has financed a joint (6 month) investigation between CARESS and Personics to investigate this further.
- Personics proposal for development of an integrated user system is innovative and would make the technology accessible for children, disabled persons and those under rehabilitation.

We therefore consider the Personics prototype and proposed system newsworthy and highly applicable to solving the current challenges in work with disabilities and brain injury rehabilitation.

CARESS has produced a wealth of new ideas, which can now be exploited in a follow-on research project. We intend placing this within the Personics framework to exploit the versatility of its sensors and the proposed modular software architecture.

Please do not hesitate to contact us if you need further information.

Yours sincerely,

A handwritten signature in black ink, appearing to be "C. Carey", written over a horizontal line.A small, handwritten mark or flourish, possibly a checkmark or a stylized letter, located at the bottom left of the page.

January 15, 2001

To whom this may concern,

I have been asked to comment on Personics system and its marketability in the United States. I am the field operations manager for a Contract Research Organization (CRO) that participates in the testing of pharmaceutical and medical device products for FDA approval. In addition, I have been employed in the medical device industry as a research and education coordinator and product manager. I have from my education and experience a thorough knowledge of product and distribution requirements in the medical field as well as patient compensation procedures.

I had the opportunity to review and evaluate the Personics prototype this past summer in Aarhus as well as observe the therapeutic benefits during patient use. I have worked with numerous rehabilitative products, reviewed existing assisted technology products that exist in the United States marketplace and find that nothing like this exists in North America. It is a unique development. The application of Personics is widespread because its use is not limited to one type of patient population. According to the Centers for Disease Control (CDC), there are 250,000 Spinal Cord Injured patients living in the U.S (11,000 New cases per year), 700,000 strokes each year, 7.5 million mentally retarded individuals living in the U.S., and 400,000 autistic individuals living in the U.S.

Personics can be distributed and used in hospitals and free standing occupational and physical therapy clinics. Moreover, it can be a modality used in the home since therapeutic treatments are not limited to a hospital-based clinic in the U.S. The use of the Internet as a communication tool between patient and clinic is particularly useful in our market where Internet use is free.

In addition, there are agencies such as AdvaMed, that promote national policies that ensure patient access to advanced innovative medical technologies and they are the largest medical trade association in the world.

The functionality of the Personics system would classify it as a biofeedback system under the American FDA and insurance procedures. Biofeedback is a recognized and reimbursed therapeutic modality in the United States. As a result, if FDA approval is required, Personics would be considered a FDA Class II device requiring 510K clearance. This type of clearance can take 12 months or less. It is possible that Personics can be taken in use and reimbursed as a Class I therapeutic tool. This is possible due to the fact that Personics sensor interface requires no physical contact with the patient. This type of approval would take a maximum of three months. Once the product is developed it can be submitted for approval, which will determine whether the system is considered Class I or II.

I believe that the Personics system will revolutionize the therapeutic modality market by offering practitioners from diverse fields a whole new approach to treatment. It will be an affordable and usable system either in the clinic or at home. I anticipate the commercial availability of this product to be a therapeutic and business success in the United States as well as easily embraced by the therapeutic community.

If you have any questions for require additional information, please contact me.

Sincerely,

Donna M. Berk, MS  
Field Operations Manager  
dberk@bestcro.com



Anthony Brooks  
SoundscapeS  
Heibergsgade 21kld  
DK 8000 Aarhus C  
Denmark

July 23, 1999

Dear Mr. Brooks:

The Biofeedback Society of New York is very interested in hearing more about your (VIS) Virtual Interactive Space concept, and it's potential therapeutic applications for a variety of patient populations. The BSNY is a non-profit educational and political group. It supports it's members, and new techniques, information and technology to help patients seeking Biofeedback treatment. We feel that VIS could be considered a form of Biofeedback, and a highly motivating one at that. It was a pleasure to meet you and experience VIS at the Integrative Medicine Conference at Omega Institute this past June.

We would like very much to meet with you as soon as you are able to come to New York. Please let us know exactly when we could meet with you to learn more about this concept and how we might be able to help you to promote it's use in the United States.

Thank you for your kind attention in this matter.

Sincerely yours,

Susan E. Antelis, MPS, ATR  
Certified Sr. Fellow BCIA  
Executive Director of the BSNY

The Biofeedback Society of New York  
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CENTER FOR IT-FORSKNING  
THE DANISH NATIONAL  
CENTRE FOR IT RESEARCH

Til hvem det måtte vedkomme



16 JAN 2001

Århus, den 15.01.01

CIT

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#### **Vedr.: Personics systems and Virtual Reality (VR)**

Personics er af Center for Avanceret Visualisering og Interaktion (CAVI), blevet inviteret til at installere deres systemer i vores nye faciliteter, i en demonstrationsperiode.

Vi har således siden 12. december 2000 og indtil d.d. haft mulighed for at vurdere Personics prototype systemer og koncepter.

CAVI er en helt ny facilitet, bygget i et samarbejde mellem Århus Universitet, Alexandra Instituttet og Center for IT-forskning (CIT). CAVI er et center hvor forskning og industri mødes, omkring anvendelse og forskning i de nyeste systemer til udvikling af VR og interaktion. For yderligere information: <http://cavi.alexandra.dk>

VR, der er en "realtids visualisering", kræver meget store computerkræfter og avancerede projektionssystemer til at beregne og visualisere 3D modeller, med en helt specifik teknik. For at kunne opleve effekten af VR på CAVI's Holobenchen eller Panorama-biograf, anvendes specielle VR-briller. Brillerne giver tilskueren en illusion af at modellen "træder ud af lærredet" og befinder sig ude i et 3D rum. Brillerne adapterer altså billederne til menneskets øjne.

Vi betragter Personics som et nyt koncept, der kan bruges selvstændigt på en almindelig pc'er eller anvendes i kombination med andre systemer, såsom CAVI's store VR biograf og tunge SGI supercomputere. Personics kan ikke sammenlignes med VR idet Personics' systemer kan anvendes med adskillige type multimedie effekter, hvoraf VR kun er en enkelt mulighed.

Internet:  
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8942 2443

Vi anser Personics som et nyt og interessant interface til bl.a. VR, idet deres system giver mulighed for spontant og naturligt at navigere rundt i et VR miljø uden fysisk kontakt, til forskel fra de almindeligt benyttede værktøjer såsom mus, spaceball, stylus-pinde, handsker eller lign.

Idet Personics systemet adskiller sig fra hidtil kendte teknologier, har det vakt interesse hos vores tilknyttede forskere, som en ny brugerflade til VR. CAVI har fortsat interesse i at afprøve systemet indenfor VR miljøet.

Med venlig hilsen

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## **Appendix 3: Therapist report - extract**

Outcome report extract below by Physiotherapist Falkenberg (1999) – see video documentary<sup>8</sup> that includes session examples, demonstrations of movement to audiovisuals, and third party interviews with (a) physiotherapist Falkenberg who works with PMD participants, (b) physiotherapist Dr Gitte Rasmussen, who works at CRBI with ABI patients, and (c) parents of a SoundScapes PMD participant. In a written statement Falkenberg evaluated improvements in:

- Training with causality
- Training with gross motor skill (arm)
- Eye hand coordination
- Eye-eye contact
- Change between hard and easy tasks
- Possibilities for imitation tasks
- Working with hands
- Eye tracking
- Improved concentration
- Increased motivation
- Improved communication
- Safe, natural and personal contact
- Experience of control
- Trust
- Improved body language expression
- Reduced learning curve over existing tools
- Improved auditory association
- Reduced stress
- Reduced spasm attacks
- Increased relaxation
- A successful smile on conclusion of session

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<sup>8</sup> <http://www.youtube.com/user/sherman56#p/u/5/mxOV39MFzPw>



## Appendix 4: CRBI - HUMANICS Brochure (3-fold front/back) and Director's Letter

### Tests of Evaluation

#### Physiotherapeutic tests

1. Berg's Balance Scale
2. VAS (Visual Analogous Scale)
3. FQM (Functional Quality of Movement)
4. Muscle testing
5. ROM (Range Of Movement)
6. Åstrand's Bicycle Ergometer Test
7. BFI (Brief Fatigue Inventory)
8. Grooved Pegboard
9. Video recording (evaluated by independent parties)

#### Psychological tests

1. Intrinsic – Extrinsic motivation inventory
2. Word Fluency
3. Ideational Fluency (wordclass)
4. Expressional Fluency
5. Unusual Uses Task (“Brick test”)
6. Consequences/Story Ending
7. Making Objects / Tinkertoy
8. Picture Construction
9. Match Problems
10. The Nine Dot Problem
11. Ravens' advanced Progressive Matrices
12. Six-item Creativity questionnaire
13. Adjective Check List
14. Self-efficacy questionnaire
15. Video recorded open focus group interview
16. IQ measures

#### User interface

##### User Interface Questionnaire

- Prior experience with computers.
- User interface of the Personics system (ease of use, feedback, inspiration).



*The sensors register movement of the body. The patient is trying to keep a glass on a slippery tray using a shift of body balance. Other exercises and feedback modes can be chosen (eg. Using arm/hand to control drawing, colors, sound etc.)*



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Tony Brooks – Personics  
Christopher Sorensen – Personics  
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### The Humanics Project

Moving or dancing to music is joyously appreciated by most people. *Creating* music and/or pictures and light with body movement alone adds a new and different dimension to such joy.

Physical rehabilitation after acquired brain injury is often an enduring and cumbersome task to the patient, who is only encouraged if a feeling of progression is present. The aim of the **Humanics project** is to create an untraditional IT-system that would work as a supplement to traditional physiotherapeutical training. Interactivity, creativity and “challenge/success” environment are major aspects of the system. Thus making physical training a more exciting and inspiring part of life after acquired brain injury.

Since creativity and motivation are at the core of the concept for the system, the work also focuses on these (all too often ignored) aspects of rehabilitation.

The Center for Rehabilitation of Brain Injury in Copenhagen (CRBI) and Personics (A Danish based IT company) collaborate in the Humanics project, investigating and developing an easy-accessible hi-tech system that could operate in these creativity/motivational dimensions.



## Background

The HUMANICS project began in the Center for Rehabilitation of Brain Injury (CRBI) Copenhagen as short-term probe in the spring of 2000. It subsequently received funding as a one and a half year development project from the Danish government and began in April 2001. In 1997 at a conference in Aalborg, Northern Denmark, celebrating the 'Year of the Brain' in Europe, an introduction to the work of Tony Brooks was given to the director of CRBI. Subsequent patient trials hinted at the feasibility of training brain injured in rehabilitation with the concept. As a result a company called Personics was formed around the theories, ideas, concepts & methodologies of Tony Brooks. An interactive room system is now implemented at the CRBI, Copenhagen, where there is a core team working with former students/patients at the CRBI constantly relaying feedback to the system development team so as to optimise the system for the users.

## How It Works

Tony Brooks designed the system so that movement measured with 3 infrared sensors could control Sonic, Visual, Robotic and other feedback. The present system affords video and audio feedback (see ill. on reverse). The movement from the participant is captured and routed to a computer. The computer is able to translate this data into control information for the preferred feedback. The participant, from a library of instruments and images, selects this feedback. The easily operated graphical user interface is being developed to be non-intimidating to the end user (therapist or patient). Thus a supplement to traditional physical training is made approachable in an interactive, motivational 'PLAY' environment rather than an approach with specific repeated exercises.

Presently intensive work is carried out to make the interface-parameters, calibration, and data log aspects of the system recordable and recallable for repeatability between sessions so as to evaluate progress of the patient. Another feature to be implemented has been feedback of personal significance (for example a pre-recorded favourite image or sound (eg voice) of the patient - grandchild, pet etc.)



*An illustration of a sensor tracking hand movement. The infra-red sensor (invisible light to the human eye) registers movement in its field. Here a hand enters the field and affects the dynamic feedback image (in this case a hand throwing a ball). Since the sensors track only movement other parts of the body (eg. trunk, leg) could just as well be controlling the feedback which in turn could be different (e.g. music, game etc.)*

## Research Objectives

The following issues are addressed through the current study with the Personics System:

- Does Personics give patients with acquired brain injury with physical injuries, an increased physical level of activity and function?
- Does the Personics System have the potential to become a relevant and novel system, and can it increase motivation for physical rehabilitation?
- When training in the system: Is a more free style of training (e.g. no specific physiotherapeutic exercise or goal) preferable to a more restricted type of training (e.g. specific physiotherapeutic measures and aims, comparing achieved goals, etc.) or vice versa?
- Can results from the Personics System be shown to correlate with functional change measured by traditional physiotherapeutic tests? And if it can, Which functions will it be possible / desirable to measure?
- Working with the Personics System: Are creative and motivational aspects of specific activities outside the training sessions affected?
- Is implementation of the Personics System as a training measure in private homes a viable prospect?

## Patient selection

Participants were selected from a group of patients formerly enrolled in the traditional post-acute rehabilitation program at the CRBI<sup>1</sup>. At a very general level patients enrolled in this program are typically ½-3 years post-injury and are able to handle most essential ADL at a reasonable level. Exclusion criteria were inherent cerebral dysfunction, any history of psychiatric disease and substance abuse. All 12 patients in the present study continue to have physical impairment following their injury. Studies with children on an experimental level are also scheduled

## Method

The group-case study includes 12 adult patients selected among patients formerly enrolled in the CRBI rehabilitation program. Training with the Personics system is carried out over two 10-week periods. Six patients are trained in each period. During the training period an experienced rehabilitation physiotherapist individually trains all patients in one-hour sessions 2-3 times weekly. Each session consists of 20 min. of free movement and 40 min. of physiotherapist directed activity directed towards the patients needs. The entire session utilizes the Personics System. For each 10-week period all patients are individually tested following the schedule below:

- *Immediately before and after each 10-week period:* Physiotherapeutic testing including tests of general fitness, balance, level of activity, and quality of movement. Psychological testing of creativity and motivation, User Interface questionnaire.
- *At two and six and ten weeks into the training period:* Video-recorded focus group, User interface questionnaire / Personics System interface.
- *During the entire testing period:* Video-recordings are made of the actual patient/therapist sessions. These are later to be reviewed by physiotherapists external to the project.

<sup>1</sup> For further description of the CRBI rehabilitation program and patients see Pinner in Christensen et al., 2000



## Center for Hjernesgade

Center for Rehabilitation of Brain Injury

April 15, 2004

To whom it may concern

As person responsible for the Centre for Rehabilitation for Brain Injury (CRBI), located at Copenhagen University, Denmark I hereby sign that the contribution by Associate Professor Anthony Lewis Brooks - (Tony Brooks) - to the research project Humanics which was based at the Center as a government funded feasibility study in 2000 and as a full research project from 2001 was considerable and as noted below.

The Center became aware of Professor Brooks' research in 1997 at his presentation at the "European Year of the Brain" conference. His research project that was presented at the European conference was titled "SoundScapes". SoundScapes, under its guise title Personics, was the foundation and core of the Humanics research.

As a result of the initial meeting in 1997 professor Brooks conducted research in the Center for Head Injury Rehabilitation in Aarhus, - Denmark's second-largest city - and subsequently following on the research at our centre in Copenhagen.

Professor Brooks' contribution has been assessed through cumulating his various attributes which he has input to the research at the Center since 1997. These amass from his initial idea and concept; his contribution from prior research findings; his research methodology development; his practical input to the therapy sessions and participation in the research team as supervisor consultant. Professor Brooks has also represented the Center at National and International research conferences where his project was presented.

It is a difficult task to assess exactly but I would suggest that professor Brooks' contribution to the research amounted to an approximate percentage in excess of 80% when the whole research is considered.

The Center, under my signature below, gives full unlimited authorization for Anthony Lewis Brooks to utilize the material of his choice which was accumulated by the CRBI research team which contributed alongside him in the project.

Credit to the Center for Rehabilitation of Brain Injury has been agreed by Professor Brooks for inclusion in any documentation where the material is used.

On behalf of the Center for Rehabilitation of Brain Injury (Centre for Hjernesgade)

Your sincerely

Frank Humle  
Director, neuropsychologist

- 
- <sup>i</sup> <http://www.gehlhaar.org/x/pages/soundspace.htm>
- <sup>ii</sup> <http://www.soundbeam.co.uk>
- <sup>iii</sup> <http://homepage.mac.com/davidrokeby/vns.html>
- <sup>iv</sup> <http://musart.dist.unige.it/EywMain.html>
- <sup>v</sup> “c. 1994” depicts approximate year – see <http://dictionary.reference.com/browse/circa>
- <sup>vi</sup> <http://www.bristol.ac.uk/Twi-aysi>
- <sup>vii</sup> <http://www.bristol.ac.uk/carehere/>
- <sup>viii</sup> <http://cordis.europa.eu/ist/st/oprog.htm>
- <sup>ix</sup> <http://www.soundbeam.co.uk/downloads/leaflets/soundbox-leaflet.pdf>
- <sup>x</sup> The simple definition of an intelligent/robotic light is that the parameters can be remotely controlled via an electrical signal such as the DMX512 communication protocol.
- <sup>xi</sup> <http://cfh.ku.dk/english/>
- <sup>xii</sup> <http://www.bris.ac.uk/caress/>
- <sup>xiii</sup> <http://www.zoominfo.com/search#search/profile/person?personId=1312653837&targetid=profile>
- <sup>xiv</sup> <http://www.theartsweneed.org/> and <http://artsintherapy.com/default.asp>
- <sup>xv</sup> <http://www.biofeedback.net/NY/>
- <sup>xvi</sup> <http://www.cavi.dk/>
- <sup>xvii</sup> <http://vbn.aau.dk/files/14567272/pdf>
- <sup>xviii</sup> <http://www.vanfoerefonden.dk/index.php/Anthony-Lewis-Brooks/1102/0/>

# Interaction with shapes and sounds as a therapy for special needs and rehabilitation

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<http://www.emaljskolan.se>

## ABSTRACT

Causal interactive audio and visual feedback sourced from whatever faculty is available from children with severe disability and utilised within an adaptable user-friendly interactive environment that encourages, motivates, and is “fun” to participate within has proved to be a rich resource within which to research towards possibilities for the children to reach their fullest potential. This paper details the practical implementation of further (related to earlier work) various visual media; virtual reality; and associated technologies so as to further enhance the study and to verify the feasibility towards a commercial system product.

## 1. INTRODUCTION

### 1.1 Who and what?

The authors were previously involved in earlier research projects within the special needs field. One was a recent EU funded project that solely focused on the sonic aspects of interacting with sensor appliances to children of various ability and disability; another project has a longer history of researching applications of synchronous audio and visual interactions within adaptive interactive multimedia environments as applied in special needs and rehabilitation. These two projects are subsequently referenced as background below.

Our paper reports on the use, within the field of special needs and rehabilitation, of interactive feedback in the form of Virtual Reality objects, shapes, and sounds to encourage movement. The approach centers upon a novel concept/observation termed ‘aesthetic resonance’ - referring to a situation where the response to an intent is so immediate and aesthetically pleasing as to make one forget the physical movement (and often effort) involved in the conveying of the intention. In the past, such repetitive movements/exercises have been either tedious (in the rehabilitation field) or indeed impossible to achieve by previous means (in the special needs field with severely handicapped children). The potential for such a system, concept and methodology which is able to adapt to an individual user profile, in all aspects, is shown to be of great value for further academic research, commercial opportunities, and more importantly, the opportunity for an improvement in quality of life possibilities, applications in new therapy, and usage as a supplementary aid towards general well being for the participants. These potentials are further explored in our segued EU funded IST project titled CARE HERE. Results confirming the potential of this fresh approach are given.

### 1.2 Background – Sound (EU CARESS Project) – Sound/Visuals (HANDI-MIDI/SOUNDSCAPES)

Some severely handicapped children are denied to a large extent the experience of movement. This includes a denial of all that follows from this including the ability to approach, reach out, discover, manipulate and

make sense of the world around us. The world of sound, fortunately, is as accessible and available to these children as to anyone else, which enabled the EU CARESS (Creating Aesthetically Resonant EnvironmentS in Sound) Project to explore the enjoyment and benefits those children can derive from immersion in a *sonic* environment. The authors<sup>3,4</sup> were key researchers in the CARESS project and a reference to this work can be accessed through the web site <http://www.bris.ac.uk/caress>

One of the authors<sup>1</sup> established HANDI-MIDI/Soundscapes in 1987 – (initially titled HANDI-MIDI, later changing and referred hereafter as Soundscapes) – as a self-funded research and development project originating from experiences and interactions with family members with a disability. The concepts and methodologies of utilising multimedia, within his self termed Virtual Interactive Space (Brooks, A. L. 1999) as an interactive play environment to aid in quality of life, therapy and other ‘special needs’ issues developed through years of sessions in which he palpably witnessed the influencing effect that was possible within his applied ‘user-created’ interactive audio visual environments. The work has been termed as an aid to augmented and alternative communication. The desire for optimising the potential for participants’ experiences within the environments, as well as the creation of a system that could satisfy the prerequisites, drove the project to its current status as a continuing pioneering and open structured innovation.

### *1.3 Foreground – Virtual Reality (EU TWI-AYSI probe)*

The European organization i3net funded future probe Twi-aysi (The World Is – As You See It) emerged from the CARESS Project to answer the question:

Can immersion in a *visual* environment hold similar potential for such children in terms of the aesthetic resonance they might derive from *movement* within such a visual space?

Our paper reports on the technical approach and results achieved in answering this question and the fresh applications that have arisen out of its successful completion. It details our technical approach, the experiments we conducted, and the results achieved from the various multimedia environments. The evidence of technical soundness and relevance of results is supported by the photos and on-line video mentioned in the appendix.

## **2. EQUIPMENT, TECHNICAL APPROACH AND METHODOLOGY**

### *2.1 Equipment*

The Soundscapes system was used in Twi-aysi. Soundscapes refers to a concept and methodology. However, when referenced as a system, it refers to a conglomeration of equipment, assembled according to the authors’ prerequisites from prior experiences which, when incorporated as a whole, is capable of capturing body function data information (for example, movement data, breath pressure, biofeedback) which can then be used as a source for real-time interactive manipulation and control with multimedia. The capturing of the body function data information can be sourced from a selection (or a combination) from a variety of equipment: for example, sensors, cameras, biofeedback and other peripherals.

The most often chosen capture device utilised in Soundscapes has been infrared beams where movement within a single or multiple pseudo 3 dimensional area(s) which is emitted in the form of an ‘egg shaped’ infrared beam of light can capture data. The sensitivity of the areas can be easily programmed according to each individual participant. The range of the Virtual Interactive Space can be selected and created according to the desires of the participants from a mere few centimetres up to around fifteen meters by using high reflection panels. In this way small body part movements, such as a finger twitch, or full body movement, such as a standing balance rotation exercise, can be sourced for processing to affect the selected multimedia feedback.

Available visual feedback depends on the software and hardware configuration of the system. Music programs are readily available that accept the system protocol signal of MIDI. “Video Jockey” programs are becoming increasingly available; they enable a selection of triggering a basic assigned image to more sophisticated programs that enable real-time manipulation of an image – even three dimensional images & environments. The ability for the program to enable the user/therapist/family member to select images and to even scan in photographs that are personal is a prerequisite. Sound output from the Music program can also be used as an input to the readily available visualization programs via the line input to the computer. In the sessions in both Sweden and Denmark we used a basic paint program that accepted MIDI.



## 2.2 Technical approach

For the Twi-aysi sessions it was decided to begin with synchronized digital sounds with digital colouring of image sequences through mapped gestural data sourced from users movements within single and multiple infrared beams. In the Swedish sessions, a retail product called Dbeam by Interactive Light from Santa Monica, USA was utilised. This is an infrared sensor box with the above attributes. In the Danish sessions however, two prototype sensor boxes were used. The first prototype was created, designed and constructed by the author (1). The second prototype was an adaptation from three Dbeams to the authors' design assembled into a 19" rack flight case. Both prototypes consist of a three-headed infrared sensor array with each having the emitter and receiver mounted at the end of an easy flex miniature gooseneck. This was to enable minimum intervention and ease of set-up and adjustment of the interactive areas. Both prototypes are capable of capturing the movement data information that is assigned, via an easy user interface, to similar or different channels of operation within the MIDI protocol. The three channels can each be selected to transmit on either channel 1, 2, 3,...or 16, and a choice of data information can be selected (for example; note on, control change, pitch bend etc.). The range of the data information can be programmed to suit the user profile of the individual participant. The three signals are collected into one output cable to be further routed downstream to a computer via a MIDI interface.

## 2.3 Methodology

The collaboration between the prime researchers provided a wealth of experience within which to explore the application of visual media, solely beyond the sonic, within the field of special needs and specifically, with the children with severe disability. Both researchers have many years of experience with these and other similar children. To make the children comfortable, previous tried and tested technologies, user preferences (where known and applicable), and user limitations were integrated and initiated at both test locations. Thereafter, new explorations with the available technologies were selected for the user to experience such that an immersive visual experience was created to encourage the desired expression through movement that would give an indication of an aesthetic resonant achievement.

Evaluation was through Multiple Camera Analysis (MCA – Brooks, A.L. 1999) technique that entails two or more cameras set up so as to capture various views of the interaction. These cameras can matrix feed between: monitors and a switch box for live monitoring and switching, separate videocassette recorders, or directly into a video capture facility on the computer. The archived videos are synchronized so as to enable multiple view analysis for observation of all qualitative movement and other signs from the session that may be an aid towards a quantitative evaluation. MCA also enables options for camera angle switching selection in post session presentations.

# 3. DESCRIPTION AND RESULTS

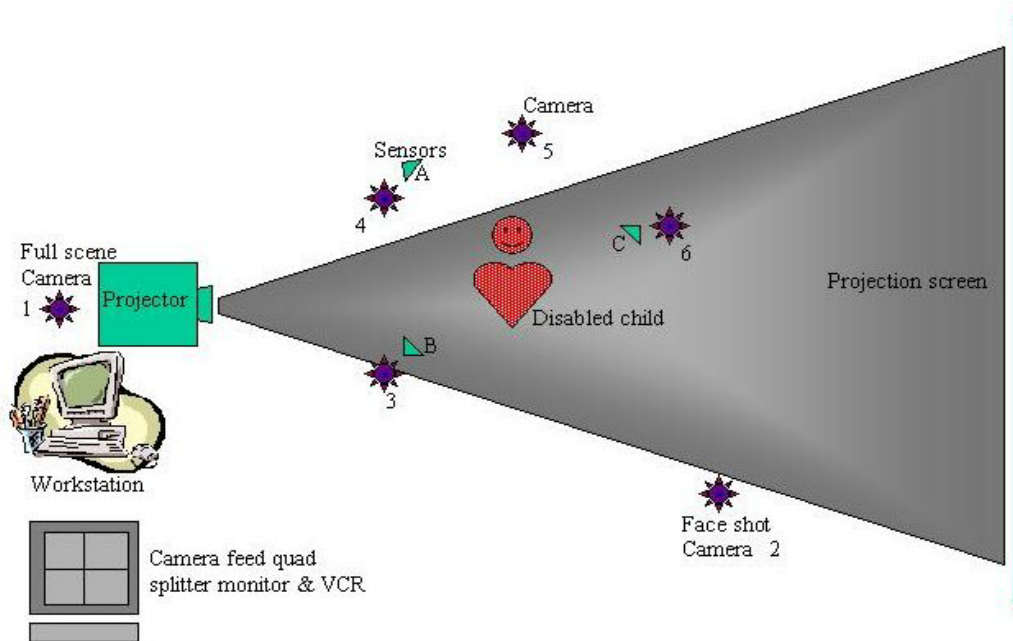
## 3.1 Sessions description - Sweden

The sessions in the special needs school in Landskrona were with eight children of mixed gender and various ages between six and seventeen, with various levels of disability. The sensor space was created with three separate sensor heads as detailed above assigned to MIDI channels 1, 2, and 3 on the hardware interface display. The signals fed a 3 to 1 merge box and subsequently the output was fed into a computer running Opcode Max. The simple patch in Max allowed the mapping of the gesture data information to a MIDI input paint program and to be output externally to a MIDI sound module and MIDI sound effect unit.

Due to delays in setting up on the first day and the user falling asleep, the sounds and images were preset before the user entered. The sensors (A, B, C) were mapped externally to 1, 2, or 3 different patches/instruments in the sound module and effect combination, and internally to the paint program to colour filters in the colour synthesizer window. This affected the Red, Green and Blue parameters so as to open the colours to input to the (black driven) sequence created by the author prior to the session. Various real-time changes were undertaken within the sessions depending on user reaction. These changes ranged from mapping all three channels to a single channel and thus instrument patch and colour, to extreme visual interactive causal sensitivity swings (varying the amount the movement caused the response).

Six cameras (1 – 6) were implemented so as to archive the sessions. Four of these cameras, which were each focused on the various expected interactive body parts fed a quad splitter and subsequently, a videocassette recorder. One camera was set up so as to record close facial expressions and another was set up

to record the whole scene. A workstation set up controlled all parameters of the session downstream of the programmed sensors.



**Figure 1.** Camera/sensor set up.

### 3.2 Sessions description - Denmark

The sessions in Denmark were with four male children with severe disability ranging in age from three to five years of age. The sessions began with three days in the Experimentarium, a large empty space, and then two days in the Panorama Virtual Reality room; both are located within the Center for Advanced Visualisation and Interactivity in Aarhus. MCA was again used with two cameras set up to archive the sessions: one camera was set for close facial expression while the other camera was set up to record the whole scene. On the first day the prototype sensors (as described above) were used in the Danish sessions in a similar manner similar to that method used in the Swedish sessions. On the second day, a further implementation enabled gesture data information to be mapped to control “intelligent lighting”. Therefore, in addition to being able to colour the image sequence, the user was able to control the X axis, Y axis and gobo pattern/colour of the robotic light from his gesture. The success of the three days of sessions encouraged the author to initiate a session on the fourth day in the Virtual Reality Panorama room for the children. This decision was confidently taken as a result of the author’s previous investigations. It resulted in the prototype sensor assembly being able to control a simple Virtual Reality environment (QuickTime VR) such that each sensor achieved a functional role similar to the usual interface - a standard mouse. Thus, the prototype in this instance became a non-tangible mouse emulator so that navigation within a 2-dimension or 3-dimension environment was possible with the added bonus of being able to dwell click on certain objects to get a predetermined simple response. It was also possible to manipulate 3D objects in a similar manner.

The VR Panorama is a room with a large parabola screen onto which is (multi) projected a stereoscopic computer-generated three-dimensional image and/or environment that can be interacted with by the use of a navigational aid (usually an assembly resembling hard –wired jointed sticks or pins which the user moves to affect the assigned parameters of the projected image). Shuttered glasses are used to view the stereo image that appears blurred to the naked eye.

The programmers at CAVI adapted an existing Virtual Reality program that enabled the prototype sensor to control a projected spacecraft that was visible in strong contrasting colours on the screen. In the individual sessions, the prototype sensor was positioned behind each child’s wheelchair. Two sensor heads, which were optimally adjusted and positioned each side to the child’s head, were required to capture his small gestures that we were told were his best form of movement.

All children responded favourably to the visual environments. Whilst all indicated individual characteristics through their interactions by their limited body movements they all at some time achieved a level of ‘aesthetic resonance’. The evaluation of the synchronized videos from the Multiple Camera Analysis

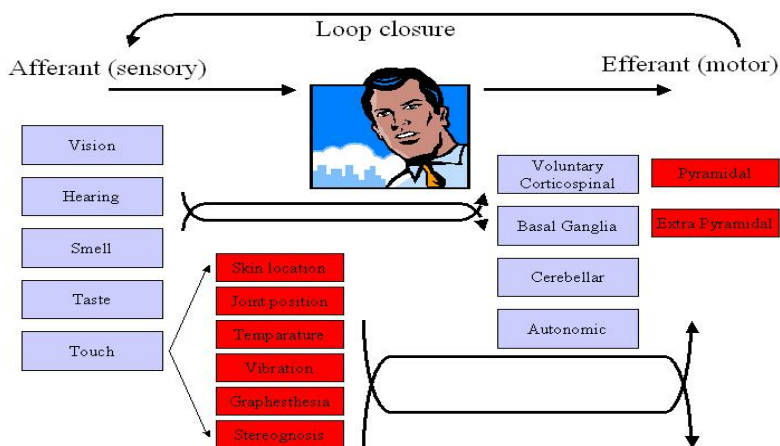
technique proved an invaluable aid: it enabled us to observe that certain movements or facial expressions which otherwise may have been overlooked allowed us to correlate the specific causal chain effect.

### 3.3 Results – Sweden

A negative aspect about the sessions in Sweden was the intervention that had to be initiated by the authors so as to set up the interactive space to the desirable sensitivity and position. This was further hindered by the size of the sensor boxes (30cm x 16 cm x 3cm) and the many wires that encumbered the working area. It was also observed by the author that often the child would lose focus on the interactive feedback due to the distraction of a small movement in the room. Future research has been planned within two rooms divided by a two-way mirror so that the child can be alone in the virtual interactive space yet still closely monitored for any signs of discomfort with related ethical rules abided by.

However, despite the negative issues raised in the paragraph above, the sessions were classified as a success: once an optimum feedback was achieved, it was obvious through the child's facial expression that a higher nuance of concentration was attained.

Our observations led us to conclude there was an overall distinct increase in motivational intent in the children. We witnessed instances where an initial subconscious (unintentional) efferent (motor) action by the child led to a definable cognitive experience (through the manipulation of the feedback as a result of the action). We would suggest that this afferent (sensory) stimulation led to an intentional (conscious) reaction resulting in the causal interactive motivation that would suggest a closure of the neural afferent/efferent loop.



**Figure 2.** *The afferent/efferent loop.*

### 3.4 Results - Denmark

As stated above the three days in the Experimentarium were a success and the extended prototype sensor control to 'robotic intelligent lights' from the author's earlier work again highlighted the point that a feedback of physical movement relative to physical movement proved to be a strong stimulating feedback for the users.

Three of the four children were very comfortable in the Virtual Reality Panorama environment. However, the fourth had a problem with achieving a comfortable position in the sensor space (his preferred position was on his back) that was further hindered by his feeling under the weather on both days according to the helper.

As expected, all refused to wear the shuttered glasses required for viewing the Virtual Reality projected image. This may be alleviated over time with more tries and probably – more importantly – the requirement for an adaptable fitting would be an aid as the shuttered glasses available were one size only and thus too large for the children. As a result, the projected image was driven in mono.

One session in particular resulted in an extended aesthetical resonant response from a child who very quickly demonstrated an understanding for the virtual interactive space. The recordings from this specific session were subsequently synchronized into a blended video file by the author and are accessible via url <http://media.nis.sdu.dk/video/twi-aysi.html>.



This video shows a five-year-old multi-handicapped boy who depends entirely upon his wheelchair. He can hear and has very limited vision but notices strong colours and is able to follow images with his eyes. He is unable to communicate verbally, but his helper told us that the sounds he is capable of making are indicative of enjoyment in the task in which he is involved. This is the first time he tried to control the spacecraft.

With a small gesture to the right, the rocket ship points to the right; a movement left and the rocket ship points left; a head movement down and the ship's nose tips down as if to dive; and a head movement backwards and the ship's nose tips up as if to climb. In the video an obvious conscious vigorous shake of the head from side to side is reciprocated by the spacecraft's corresponding response. The young disabled boy was only able to express himself through a single verbal expression (a sort of repeated "AYYE" phrase). While in the session and immersed in the 'aesthetic resonant' interaction, (as can be appreciated on the video), he could clearly be heard making his sounds that when interpreted by his helper as an expression of a joyful experience.

In a following experimental session the two infrared sensors were set up and programmed at long distance. They still were sending MIDI data through the same mapping network to control the VR spacecraft. With this space it was possible to still move the spacecraft but without the fixation of location of sensor head as in the short range detailed above with the five year old child. This then became a further exploration of the two sensor spaces through the interactive feedback (i.e. manipulation of the spacecraft). It was discovered to be a much more intuitive experience as body gesture, weight shift and rotation (for example) made a corresponding change to the spacecraft. Thus, a form of 2D and/or 3D navigation in Virtual Reality with non-wearable equipment at long distance, using just a small movement in the interactive space similar to the QuickTime Virtual Reality described earlier, was achievable. A possible improvement for the interaction would have been from a pilots' view.

In Sweden there were many positive responses given by both staff and families who witnessed the sessions. In Denmark, the children's helpers were positive and especially remarked upon an improved vocal communication over the following weeks by the children. A subsequent session provided further proof as a stronger verbal expression could be detected and it is proposed to utilise this as a quantitative measurable in the future research. The reactions of the child in the video provided the most obvious proof of 'aesthetic resonance' through VR visuals, matching the experience with sound we had observed in our earlier work. Virtual Environments combining sound and visual stimuli were an obvious next step.

#### 4. CONCLUSIONS

The main conclusions we have drawn from the Twi-aysi work are as follows:

- Immersion in a visual environment *can* hold similar potential to immersion in an audible environment for such children. Indeed, we were ourselves surprised how readily aesthetic resonance could be observed in such children moving within the quite crude (and sometimes silent) visual spaces we assembled.
- The attraction and advantages of using neither wearable not touchable sensors but merely exploiting the childrens' unencumbered movement through space was readily apparent. The need for cumbersome virtual reality headsets or indeed *any* physical attachments would seem at this stage both undesirable and unnecessary for achieving satisfactory states of aesthetic resonance (see for example the video <http://media.nis.sdu.dk/video/twi-aysi.html> and pictures below).
- It was apparent that when the individual feedback was singular, certain users were more perceptible to audio while others were more perceptible to visual stimuli. When the two elements were simultaneously available and triggered through interactive captured movement, a greater degree of immersion was observed.
- Virtual Reality in its current state is not an answer because of the head/eye equipment needed to view it. However, the researchers believe that a cave environment would add to the immersive experience and as such be an aid towards 'aesthetic resonance.' The non-tangible navigation in the 2D & 3D environment that was achieved will also be implemented in further research where appropriate.

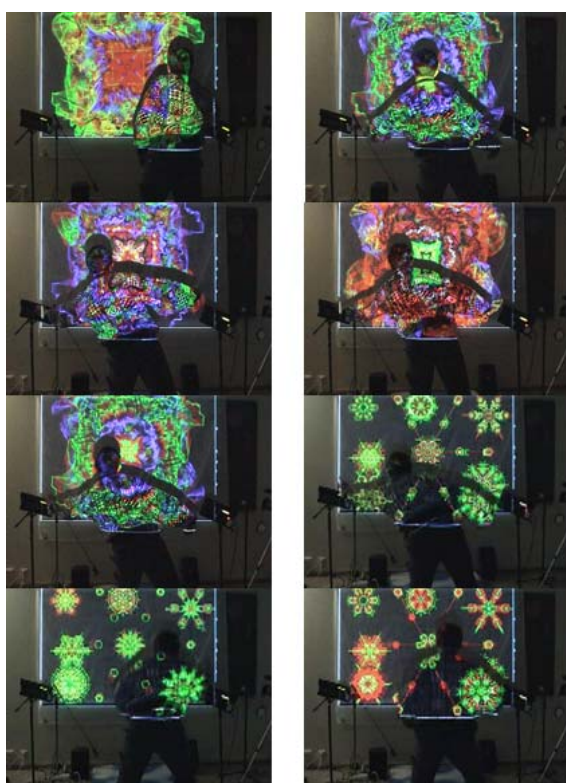
**Acknowledgements.** Ron Laborde, Bristol University, UK; Staff and children involved at both research locations in Sweden and Denmark.

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## APPENDIX

### *Extracts from the Swedish Sessions*



**Figure 3.** A cerebral palsy child achieving Aesthetic Resonance within his virtual environment as a result of responding to colour feedback to his own movement in space. The motivation that was achieved through the immersion in a visual interactive space is obvious as the variation in colour indicates a dynamic movement in all three zones and as the pictures progress down the page an increase in body movement can be observed. This session in Sweden resulted in the child pushing his physical limits without realising until afterwards when he said that he was so tired, and still he returned to the space for further interaction.



**Figure 4.** The images above show a wheelchair bound disabled child photographed from behind. The child sits in an interactive space created from three infrared sensors and in close proximity in front of a screen because of his poor eyesight. A speaker is positioned close to him for his monitoring of the audio sounds that he is manipulating through movement. He is also manipulating the colours of the “Doughnut” through moving into the interactive area of the each sensor (each designated 1 = Red, 2 = Green & 3 = Blue). The progression from upper left to bottom right in the series of photographs illustrates a progressive increase in movement that can be seen by the increase in “doughnut rings” and the colour references indicate which area/sensor is being activated. In the sessions the three different sounds being triggered were further indication.



**Figure 5.** The upper image shows the disabled child from Denmark viewed from the front camera (large image), with rear camera showing the spacecraft that he was controlling with his head gestures, (inset lowerright). A video of this session is available on-line. (<http://media.nis.sdu.dk/video/twi-aysi.html>).



**Figure 6.** The lower shot is a reverse image of the Virtual Reality set-up at the Panorama room CAVI (Center for Advanced Visualisation and Interactivity) in Denmark with the child in a wheelchair (centre) with two sensors (over/behind = the thin lines;) the helper is sat beside him (centre right). A camera with night vision was set up so as to capture his facial expressions and the spacecraft was projected onto the panorama screen. A second camera was set up behind to capture the total scene.

# Robotic synchronized to human gesture as a virtual coach in (re)habilitation therapy.

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## **Abstract**

This paper describes the latest developments of the SoundScapes [Brooks 2004] body of research which is utilizing technology in assistive rehabilitation and habilitation from Virtual Interactive Space (VIS) [Brooks 1999]. This paper exhibits the implementation of robotic physical movement synchronously manipulated from sourced data movement information of a human. The user groups are children with severe physical/multi disabilities. The sourced capture of the human data is from enhanced virtual interactive space created from sensors. The results highlight the positive effect of physical control by those with limited facility and conclude at the potential of implementation as a supplement to traditional therapy techniques.

## **Keywords**

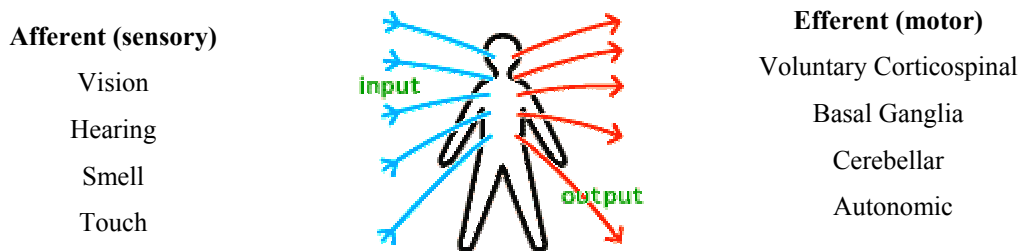
Robotics, Memory, Cognition, Gesture, Motivation, Consciousness, Play, Interactive, Empowerment, Control, Sensors.

## **1. Introduction**

If one searches for the term <virtual coach> on the World Wide Web it brings up links that offer ‘*telephone coaching*’; ‘*CyberCoaching*’ (by e-mail); and – “*combinations using state-of-the art conference call systems for interactive and dynamic TeleForums!*”

This paper is suggesting a somewhat different approach for the investigation of a virtual coach. An approach away from The Web where through empowering human gesture to control synchronous robotic movement and multimedia feedback severe disabled children are encouraged to “play” utilizing whatever physical ability they may have. This “play” element is the apparent and upper-most level which is perceived and which encourages immersive state through interaction. Other not so easily perceived levels are inherent which through this study suggest at potentials as a new tool for therapeutic supplement as a virtual coach. This presented study is contained within a larger body of research titled SoundScapes which is based on the stimulation of the human consciousness through proactive interactive “play” experiences and empowerment. In SoundScapes new technologies are utilized to enable controlled manipulation of physical robotic devices, computer programs and other interesting feedback. The research has been expertly appraised as giving potential in human afferent efferent (often called sensorimotor) neural loop closure (see figure 1).

A “virtual coach” for therapy should be complimentary so as to contribute as a supplement to traditional practices. It should in no way deter from the therapy or interfere with the patient’s well-being. It should be motivational and inspiring for both therapist and user such that in certain instances, non-verbal communication and expressive cues, which are inherent through fun interactions, are encouraged and utilized in the therapy.



**Figure 1:** Human Neural Loop.

When working within the human sciences certain individuality must be adopted so as to account for varying faculty, preferences and limitation. An ability by the therapist to improvise within the ‘patient-therapist’ sessions is an obvious advantage and this comes about through knowledge of the tools and the subject. The content of this paper details the use of ‘intelligent’ robotic devices which respond directly to human gesture and which can supplement the “tool box” of the contemporary therapist. Through empirical testing the author has developed a theory where such devices are suggested as being a potential interesting ‘virtual coach’ for therapeutic activities. This theory, while utilizing robotic devices that are very different from the state of the art (see section 2.1), shares common keywords to related research in the field. The added real-time synchronized response, however, that is achievable through the mapping of captured human gesture in ‘activated air’ to robotic movement gives an opportunity for a new body of interdisciplinary investigation to explore and advance the field.

## 2. Background

The concept and methodology of SoundScapes began through interactions with severe disabled family members. It was developed into a research body of work from around 1993 following its initial seeding period from 1986 where proof of concept experiments began. The author claims tacit knowledge in the field from almost half a century of interactions with his disabled relatives and subsequently through his research in the field. This paper is a legacy from sessions with the same group of children that were investigated in a Panorama Virtual Reality environment in 2001 where they were studied controlling a space ship through gestured head movements [Brooks et al 2002]. That study titled TWI-AYSI (The World Is As You See It) was the feasibility of a resulting European funded project titled CAREHERE<sup>1</sup> (Creating Aesthetic Resonant Environments for Handicapped, Elderly and REhabilitation) [Brooks et al 2004] which was based around the work. However no robotic devices were researched in those projects as is evident from the publications.

### 2.1. Interaction, Therapy, and Theory

Studies on the interaction between humans and human, and human and machines point to the fact that through interaction a level of understanding is achievable that is often relative to the length of the time of interaction. Longer interactions usually lead to a desire for subsequent interactions which stimulate; resulting in motivations of behavior being generated.

In the last decade robotic devices have been created specifically for human interaction so as to motivate subsequent behavior [Shibata 1997]. These devices have been used in children’s wards and elderly wards in hospitals as well as at senior-citizens homes in ‘robot-therapy’ sessions. In Japan, where positive results from the inquiry is reported with many users referring to the devices as “cute” and having a preference for time passing by interactive “play with robots” over the usual switching on the radio or television.

Scientists are positive - towards the ideal results of potential huge savings in medical costs, reduced burdens on families and caretakers, and healthier and happier aged - as forecasts predict of an overwhelming elderly population in the future<sup>2</sup>. The device utilized in this study was not designed for use in hospitals, or homes, or created specifically for human interaction such as researched here. The device is a stage light robot.

Robot therapy is not new. Hogan [1996] details the training of an arm of a person disabled by a stroke which is interacting with a device resembling a robotic arm which could measure the force being exerted by the user.

<sup>1</sup> <http://www.bris.ac.uk/carehere/>

<sup>2</sup> *In gadget loving Japan, robots get hugs in therapy sessions.* USA Today 11/4/2004 (The Associate Press, journalist Yuri Kageyama)

This study had a different objective which was to create a wireless non tangible link between the human and robotic coach and to create an interaction where the user feels in control. Empowerment of all users to be able to establish and maintain such a symbiotic relationship with a robotic agent without being encumbered with attachments and wires is paramount to the study. The theory offered from this research is towards the virtuality of potential opportunities in therapeutic coaching from a simple interaction – a human having fun controlling an interactive synchronous responsive robotic device.

## 2.2. Play, Interaction, Creation and empowerment.

A child moves his head 5 millimeters and three robotic devices physically respond and rotate their projection heads in a synchronized whirling ‘ballet’ of gestured interaction resulting in a “dance” of lights across the walls and ceiling of the laboratory. Correspondingly the same gesture “plays” a musical sequence through a sound system. The child follows the lights with his eyes and moves his head accordingly; he stills, looks and listens, smiles and continues to explore the invisible sensor space of the system exhibiting playful immersed interactive control of the robotic lights until exhausted.

The definition of play, as offered by the great Danish scholar of child play, Erik Erikson [1977] in his Harvard Godkin Lectures, is “*the illusion of mastery over life’s circumstances.*” Play is closely related to creation, and when watching children at play it is often amazing how they fantasize through role creation, scene creation and interactions where they create together. As adults, the creativity and play are often mostly associated to artistic pursuits such as in music, theatre, sculpture and painting or to sports. The aesthetic philosopher and play commentator Karl Groos (1898) is credited with recognizing the comparisons between play and artistic activity. He regarded play as a simplified form of artistic creation. Although the research was deemed misguided, naïve and incomplete [Beach 1945, Loizos 1966] - the author questions if Groos’ findings were so unfounded due to the findings in his own research that one may reflect upon in respect to play, creation and artistic activities.

This paper is written nearly 30 years after E. O. Wilson (1975 p. 164) had observed, “no behavioral concept has proved more ill-defined, elusive, controversial, and even unfashionable than play,” the author reflects on the fact that “play” has evolved from being “unfashionable,” to being a learned subject of inquiry and of great interest for scientists possibly explicitly due to its elusive and controversial qualities. Robert Fagan (1981 p. 5) in his contributing publication purposed to the definition of a biological approach to animal play in relation to scientific knowledge about social behavior and development, states the case of “*play behaviors representing structural transformations and functional rehearsals or generalizations of behaviors or behavioral sequences*” depending on the characterization used and on underlying assumptions about behavior classification and how, relative to context, play behaviors “*yield relatively specific and immediate beneficial effects.*” Behavior indicating play sequences and structured transformations are in our case based on gesture of the user where it is clearly observed that a deliberate exploration of the created ‘virtual interactive space’ is subjected to transformations between sequences whereby the user is able to detect the causality of affecting interaction with the robotic device. Fagan further suggests that ‘*using a tool*’ is an example of such effects and within this study we focus upon the use of our robotic device centered system as the “tool” for the therapist to utilize as a virtual coach towards the yielding of beneficial effects. Such *beneficial effects* are specific to each individual user.

## 3. Objectives

The objective of this study was to observe interaction between children with severe disabilities and responsive ‘synchronous to gesture in real-time’ robotic devices to determine if there is a potential as a virtual coach. In this way it may be possible to define characteristics of a robotic virtual coach for use in rehabilitation and habilitation, as a supplement to traditional therapy. Such characteristics are suggested as an inherent layered approach which has at the top-most level an interactive causality of “play” environment that is experienced proactively by the user. The environment has feedback qualities which are tailored to each individual user’s faculties, preferences and desires so as to be conducive to immersive interaction. Creativity is an element of the concept and methodology. So too are the task oriented interactions which can explore the limit of the user (by proximity) relative to the user’s therapy goal. An example of this strategy is where a hand movement is being trained and it is focused as being interactive to a feedback which achieves a level of success for the user. Such as playing a series of music tones, painting a color or manipulating a robotic agent. As the sessions progress the interactive space which enables the success factor is correspondingly more difficult to reach as the therapist sequentially directs. In this way the user is self-motivated towards pushing their limit to reach a previously attained goal, by extending their limit, which is the goal of the therapy. Thus the levels, content and strategy co-exist and the objective of the research is to ascertain if such a theory has valid grounding for further inquiry.



## 4. Methods

The institutes involved were asked to volunteer children who were all able to see and hear. It was not determined how much they could see but only that they were able to follow objects with their eyes. The children were to be selected from the group that is classified in Scandinavia as multi-disabled. At all sessions there was a knowledgeable helper/assistant close by to ensure no discomfort for the child. Four children were selected in Denmark and eight were selected in Sweden at the start of the full study. The range of ages was from 3 and half years old to seventeen years old. The four children in Denmark were the only ones that used robotic synchronized control to their gestures, their age ranged from 3 and a half years to 5 years of age and they were all male gender. The extent of this study focuses on these Danish children and the interaction to the robotic interaction as a potential “virtual coach”. Previously the same Danish children were investigated in a Virtual Reality (VR) panorama environment corresponding to the children in Sweden who had only sound and visuals and vibrations. A reflection to the earlier sessions with the Swedish children is referenced in this paper. The earlier report on the study on the Swedish children without robotics and the Danish children with the VR is referenced in publication [Brooks *et al* 2002].

### 4.1. Session method

It was decided to set up a basic child assessment coding scale for each session by asking the assistant how the child was at the start of every session, how he was perceived by her during the session, and how he was following return to the institute. In the analysis of the session video tapes a coding was set up to establish during the sessions what was observed. These indicators of the user’s sense of awareness were compiled into giving an insight to the use of the robotic device as a potential virtual coach for therapy. The knowledge of the user who is involved in each session is also important as a predictive estimate can be visualized for what range of signals will be obtained from the body gesture in the sensor space. This determines sensor selection and set up of the sensors as well as the programming of the range of the light pan and tilt to ensure that a full turn of the head facility can view the full extent of traverse of the light pattern. This encourages the virtual coach to motivate the user to exercise the neck by turning of the head as well as the gesture selected being exercised. Sound selection was also an issue as to whether the child liked aggressive or smoothing sounds. The assistants were able to give advice on the child’s preferences and dislikes as well as abilities and limitations.

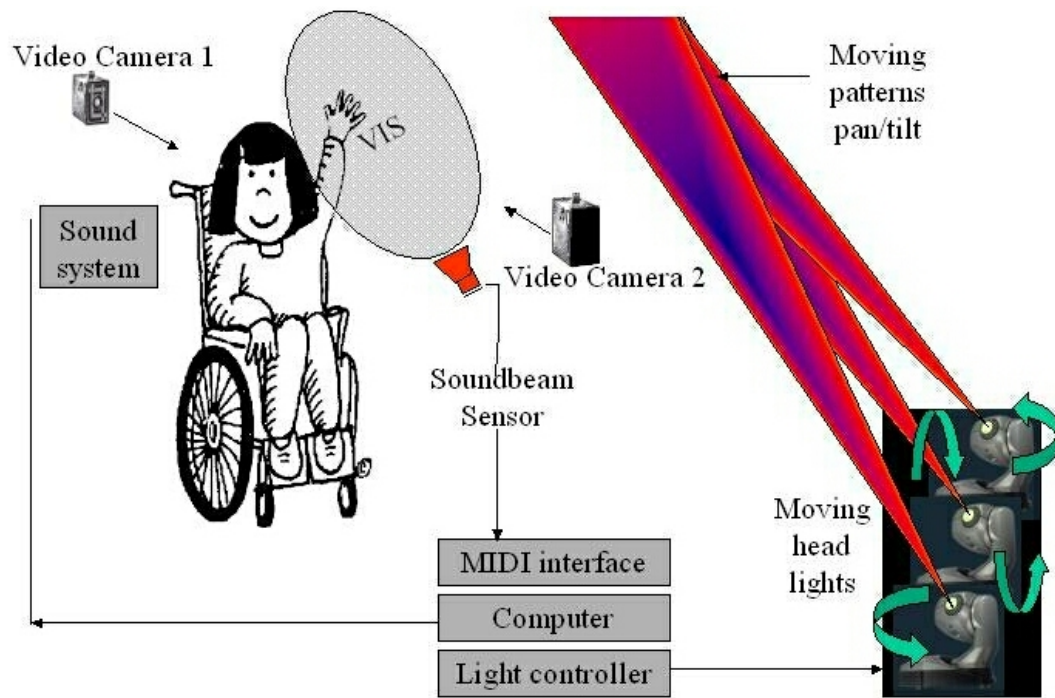
#### Hardware –

An 8 channel moving light controller (Elektralite CP10) capable of translation of MIDI to DMX 512 was central to the system. The ‘intelligent’ robotic devices that project light patterns are controlled by the DMX 512 protocol. Testing prior to the user groups being involved was with robotic intelligent lighting devices supplied by the Martin Group, a global leader in the field of stage lighting, so as to choose the optimal units for the study.

Unit reference	Dichroic Colors	Gobos	Type	Pan (x)/Tilt (y) micro-step
Roboscan 812	11 (+w)	11	Scanner	175 x 83
Roboscan 518	17 (+w)	5	Scanner	180 x 90
Roboscan Pro 218	17 +2 (+w)	18	Scanner	180 x 90
Robocolor Pro 400	32 (+w)	3 (7/14/21)	Effect	0
Destroyer X250	7 (+5w)	12	Effect	0
Robocolor 11	11 (+w)	0	Effect	0
<b>MiniMAC Profile</b>	<b>12</b>	<b>7</b>	<b>Moving head</b>	<b>540 x 270</b>

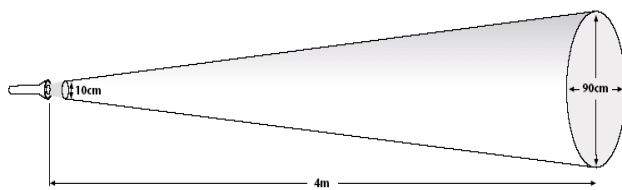
**Table 1:** Characteristics of the tested robotic devices.

The robotic device chosen was the moving head MiniMAC Profile intelligent lighting unit that projects multi-color light patterns of high contrast at up to 540 degrees of pan and up to 270 degrees of tilt. Such light patterns for a child may relate to a Tivoli, firework display or other fun experience so as to achieve the desired “play” feel of the interaction. However in this study the child (as user) was empowered to control the “fireworks!” For the research sessions the Martin group supplied three MiniMAC Profile moving head units.

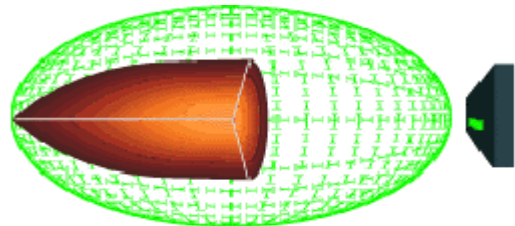


**Figure 2:** Set up of system. Human gesture captured by sensor for feedback manipulation.

The set up of the sessions was in a large empty room so that the full range of the robotic moving heads could be programmed to extend beyond the users peripheral field of view so that a head movement, (= neck exercise) was required to observe at full extremities. As shown in figure 2, the user was positioned near the center of the room with a camera behind to capture the whole scene. A second camera was positioned in front to capture gesture and facial expression. A sensor (a Soundbeam ultrasound unit – see also figure 3) is set up according to the user faculty of movement – shown in figure as hand and head gesture capture. Other sensors used were infrared volumetric sensors (author prototypes – figure 4). Gesture signal from the sensor capture is transmitted as a MIDI<sup>3</sup> signal to an interface, PC and a sound module and speaker array. The software algorithm used for mapping of the MIDI signal is sent to the lighting controller for translation into the light protocol of DMX 512.



**Figure 3:** Soundbeam linear ultrasound sensor.



**Figure 4:** Infrared volumetric sensor.

### Software –

Programming the units to respond to MIDI was with the use of an object oriented graphical programming environment which is used for music, audio and multimedia. This software (Max / MSP) is an industry standard for the mapping of MIDI data stream information. The mapping of the data information to the robotic movement and end lighting effect is a main task when setting up the system. Knowing the range of each lamp and each specific channel of communication to each unit is imperative so as to avoid confusion. Each time the units are set up in a new location a new system set up has to be programmed. On average at least half a day is needed to set up and then another half day for fine tuning the system.

<sup>3</sup> MIDI = Musical Instrument Digital Interface, an industry standard for communication between machines.



## 4.2. Analysis method

To analyze the videos from the sessions both camera views were synchronized so that it was possible to correlate the manipulation of the robotic heads, the manipulation of the projected light patterns on the facing walls and the gesture and facial expression of the user. A coding system was established for each child with help from the helper who was familiar with the various responses. As best as possible we tried to generalize common expressions accounting for each child having individual faculty limitations and abilities, typical features such as a smile, a mouth opening, a quieting, an eye focus, a frown, hand or lower torso movement.

## 5. Results

The three robotic moving heads are manipulated by a 5 mm gesture of the disabled child's head. The projected light patterns on the facing white wall move approximately 20 meters from their prior position. The ratio and sensitivity of gesture to resulting feedback is totally programmable and limited only by the physical constraints of the hardware and room location. The child is immersed in the dynamic exploration of what is happening under his control and is motivated to explore further through varying the range, the speed and direction of his gesture – he indicates awareness of a direct correspondence and control to the physical movement of the robot head and the subsequent movement of the lights.

The twelve picture sheet in the appendix (Figure 5) illustrates moments from the sessions where total immersion was apparent. These pictures alone cannot tell the whole story but only hint at the explorations and new experience from controlling robots that the young children with severe disabilities succeeded in achieving.

Most of the sessions lasted around 30 minutes, with the shortest at 11 minutes and the longest at 46 minutes. Each session timeline involved dynamic interaction and response showing a recurring pattern. One child was not comfortable in his chair so we accommodated by placing him on a floor mat that was adjusted for him to be able to see the light patterns. One male was asleep on entering the VIS in one session. Slowly he woke and explores the play of moving his head which is moving the physical robotic device, the projected light patterns and playing the sounds. The four young friends exhibited immersion in every session showing a distinct consciousness of intent.

As mentioned, the robotic devices used for this study are not intended for such use. They are adapted by the author for this study. This enabled an otherwise prohibitive investigation viable through corporate sponsorship of the devices. The choice of the MiniMac profile robotic intelligent light devices was astute. The units responded with a latency of around half a second which was acceptable but not optimal. We tested various gobos (patterns) and colors but could not ascertain if they were making a difference to the child.

Observations of the child following the patterns gave us an indication of his awareness. His facial expressions and exploration of the virtual interactive space suggesting that to some extent he was aware that he was empowered to manipulate the robotic device which resulted in the projected light pattern, however the author suggests further that his only conscious awareness was of the light patterns and the audible movement of the robotic device was a more sub-conscious element to be an associated element.

The sessions followed a recurring pattern similar to that statement accredited to Hutt (1966) in his publication on the subject of exploration and play in children, where it was quoted – *“inspection gives way to play, the emphasis changes from the question of “what does this object do?” to “what can I do with this object?”* The study shows that along similar lines the sequence is hereby extended with the author's subjective appraisal with further emphasis change of *“when I move - the light patterns move:” “when I move - I hear sounds:”... “when I stop moving I hear neither sounds or see the light patterns moving!” ... “Hey I'm in control here- and its fun!”* And further to suggest that the emphasis is extended to *“well nobody told what I should do, or for how long, so I will just have more fun with what I have learnt I can do with this object!”* In the sessions all children continued to explore until exhausted. The report from the assistant was positive from sessions and after return to the institute.

This is significant in respect to the goals of the author's research. By giving a means of expression, control or authority to a user, one is giving empowerment over an entity; such characterization attributes applies to an envisioned virtual coach system. In this study the empowerment can be observed through the physical signs as indication of the child's awareness of causality and this is what is useful for the exploration of validity of the author's virtual coach theory with the utilization of robot agents which with this study has reached its objectives.

## 6. Discussions and Conclusions

On reflection of the sessions, the set ups could have been improved, especially the VIS sensor locating for gesture capture from the human user. The sensor needs to be remotely controlled from a distance so as not to interfere with the user. In these sessions two set ups were used (1) three infrared sensors were used one for head and two for upper torso/hands according to faculty (2) a single ultrasound for head. An overhead sensor positioning is preferable. The optimal set up was with the single sensor for direct associations. This was because it gave a predictable space of interaction and avoided any confusion for the user. Being linear it also gave a progressive response to the gesture (light patterns, corresponding robotic moving heads and sound) as opposed to the volumetric data space of the infrared sensor which was unpredictable for the user as the same data is produced from different movements across the various axes.

With the current technology it is possible for the movement 'point of interference' to be between two events such that to the naked eye there is no perceived action yet two events are triggered. This is accounted for in the summary, however, after much analysis of the videos, occasionally some of the children hinted, through facial expression, at finite control whereby they could have been controlling without it being observable. The author questions if a heightened perception was possible from them in such instances of finite control.

The SoundScapes body of research utilizes cameras as well as sensors (infrared, ultrasound etc.) to capture user body movement. As the robotic device was projecting light patterns to achieve optimal effect for the users the rooms were in darkness for the sessions. The light changes in the dark space made it not viable to use camera systems for user capture. However such a future set up is expected to give additional information for the study.

Of note for readers who would wish to emulate the sessions is that the set up should always be prepared before the user enters into the space as often it is boring for them to wait and occasionally they fall asleep.

## Acknowledgements

The author wishes to thank institutes involved namely: Fenrishus, Aarhus, Denmark; Emaljsskolan, Landskrona, Sweden; CAVI (Center for Advanced Visualization and Interactivity), Aarhus, Denmark. Research assistant Stefan Hasselblad, Sweden and the wonderful boys and girls that were involved in the SoundScapes research.

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## 7. Appendix:

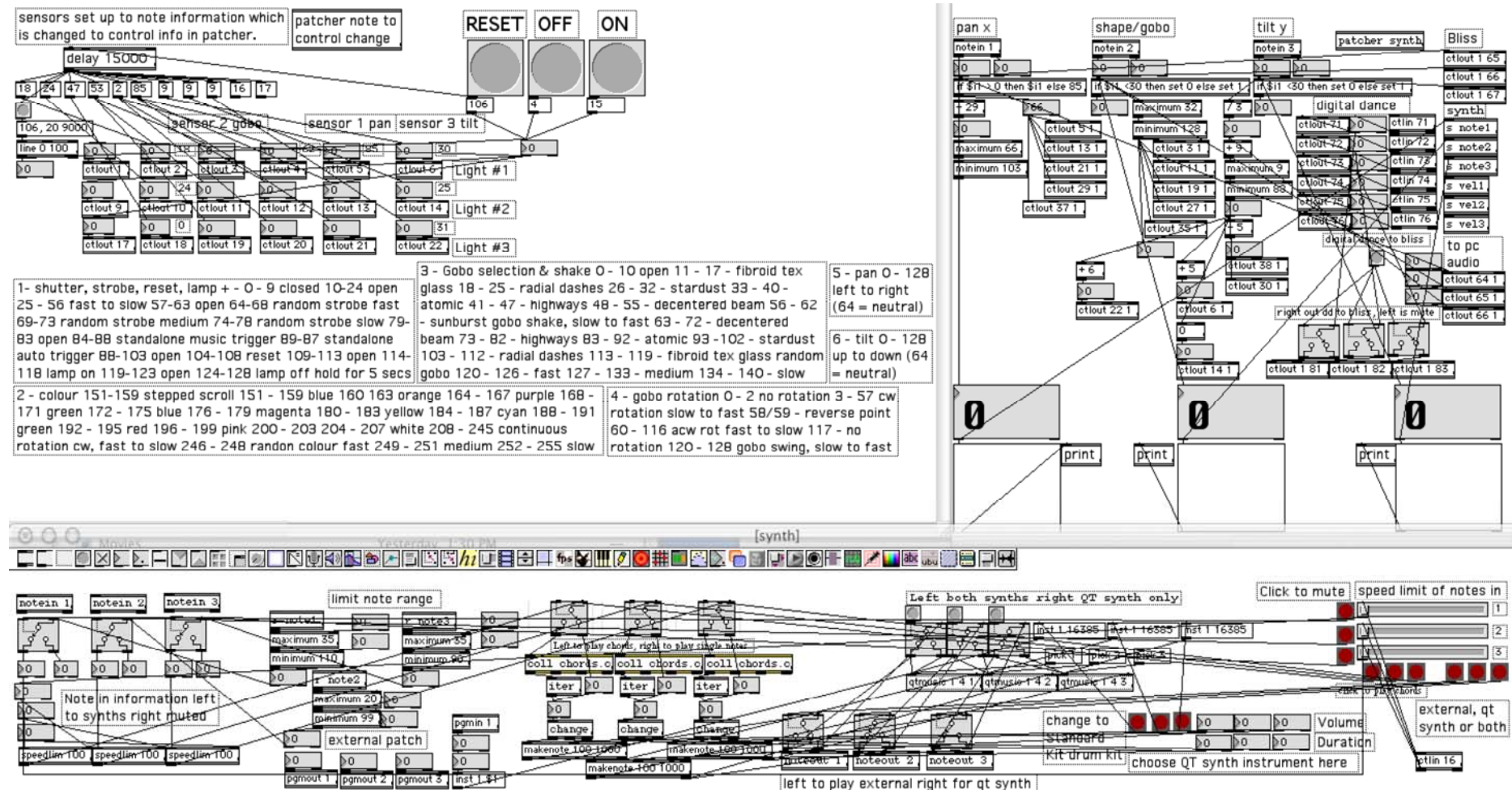


**Figure 5:** Images from sessions with the four children in Denmark<sup>4</sup>.

**A 1** – Smiling at a success; **A2** – Hard work getting the head back up to play again; **A3** – Exhausted. **B1-3** – Floor manipulation of the overhead sensors with lights on ceiling. Large extended stretching. **C1-3** – Close observation of the light patterns. A controlled ‘investigation – success – play, timeline.’ **D1-2** – Full immersion as head, hands and arms are working. **D3** - Open jaw indication of a success.

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<sup>4</sup> The photographs are low quality and this is through being captured from a video camera which was set on night vision in the dark sessions. The author apologizes but believes the content of interest for the study results.

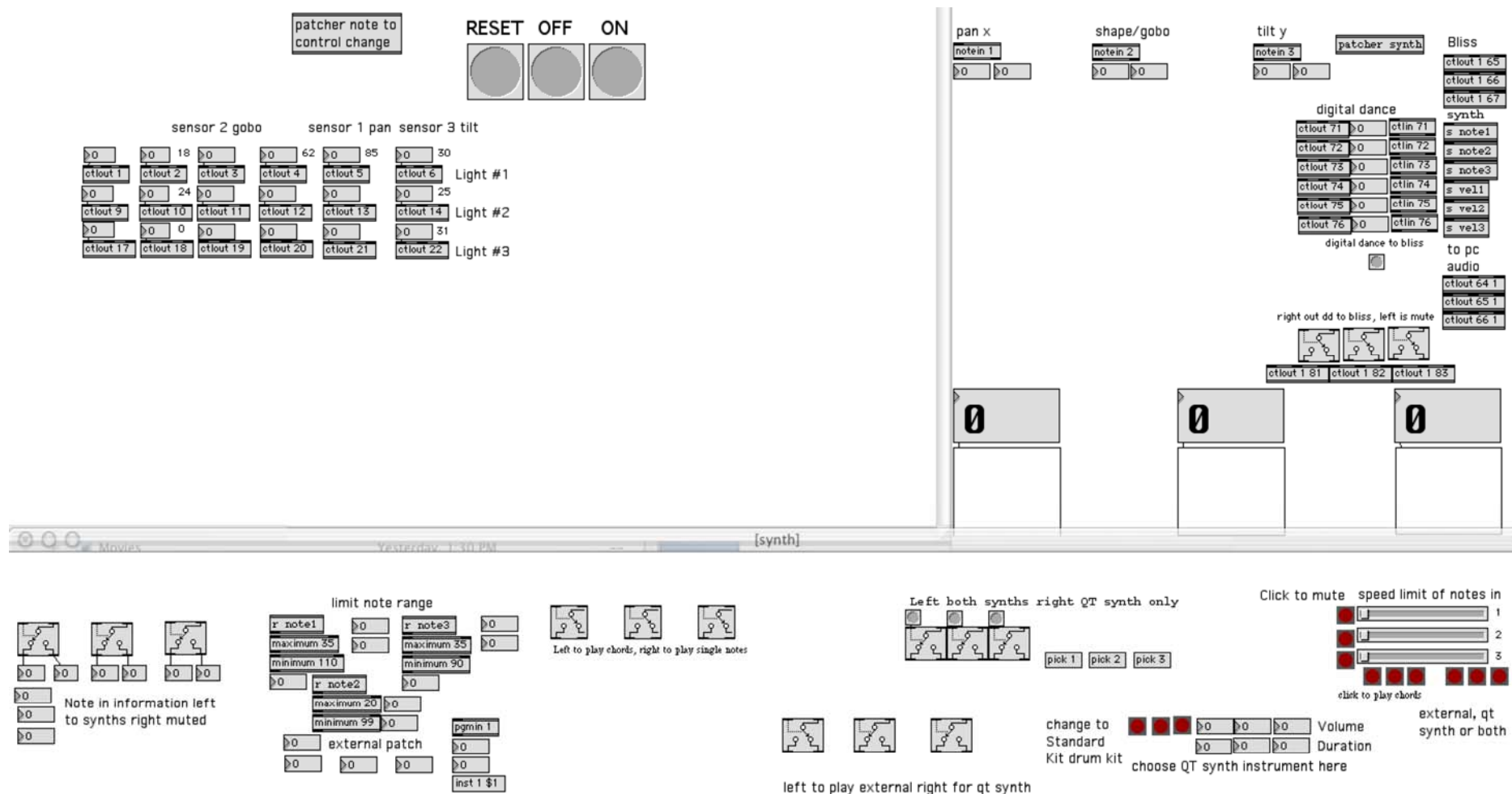


**Figure 6:** – The software MAX patch for real-time control of the robotic lights in edit mode showing the routing of the signal flows. The upper left window gives numerical read outs on the various parameters of control via the lighting controller of the robotic light devices. The top right window is the sensor input routing and limiting parameters. The lower window is the sound.



**Figure 7:** (Left) A ceiling mounted MiniMAC Profile intelligent light unit. **Figure 8** (Right) A scanner lighting device. The difference between these units of concern to the research was that a physical interaction between gesture and robotic movement was possible with the Mini Mac Profile. The early trials showed that the physical moving head of the Mini Mac Profile units gave a higher awareness for the user than the scanner devices which only enabled a moving of a mirror assembly to direct the light patterns relative to the gestures. The range of movement was also a determining factor between 540 x 270 and 180 x 90 degree of Pan (x)/Tilt (y) in micro-step increments so that a higher ration of mapping could be programmed.





**Figure 9:** The graphical user interface (GUI) for the control of the virtual coach system with robotic light devices controlled from the upper two windows and the sound synthesizer controlled from the lower window. Upper left window shows six vertical columns of number boxes giving indication of the output to controller and correspond to the sliders on the MIDI to DMX 512 controller CP10. Three rows of number boxes correspond to the number of lights – in this case 3 x Martin Mini MAC profile at 8-bit resolution (Mode 1). Three sensors 1, 2, and 3 were used in this case to correspond to columns 5, 3, and 6 respectively so that column 5 was pan control, column 6 was tilt control and column 3 was gobo (pattern) control. Upper right window shows the real-time data stream from the sensor Virtual Interactive Space (VIS) in the three large graphic and number boxes. The right hand side shows mapping options to paint, music and external PC. Digital Dance is an alternative sensor input device used for calibration and performance trials. The text boxes give read out of the various parameters that can be programmed for range. The lower window is the mapping of signals to the sound modules in the PC (such as Apple QuickTime synthesizer) or external to hardware modules or both. In this window selection of sounds that respond to the user's gesture can be programmed with separate mapping resolution in respect of constraints that may otherwise be enforced upon the robotic light range limits. Mute buttons for all sensors are able to quiet the sound so that the user can explore the visual interactions only.



# **HUMANICS 1 – a feasibility study to create a home internet based telehealth product to supplement acquired brain injury therapy**

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## **ABSTRACT**

The goal to produce a unique, cost effective, and user-friendly computer based telehealth system product which had longevity and the ability to be integrated modularly into a future internet-based health care communication provision was conceptualised as an aid to home-based self-training. This through motivated creativity with the manipulation of multimedia. The system was to be a supplementary tool for therapists. The targeted group was initially to be those with acquired brain injury. This paper details phase 1 of the product feasibility testing.

## **1. INTRODUCTION**

Acquired brain injury rehabilitation entails a long and enduring process towards training the individual to a realisation of potentials so as to be able to live a life with optimal quality following injury. Training often involves travel to a clinic which involves certain stressful situations, economic considerations as well as environmental consequences. A system design where private individuals could be motivated to train at home and utilizing the internet send their progress information to the clinic therapist for management was novel and judicious. Furthermore the all essential support from family members could provide added motivation as all are capable of ‘playing’ together with the system in the home setting. The question was asked however whether a generic system could be created that would be ‘user-friendly’ and efficient across age groups, ability groups and have continued worth over novelty value as is often seen in similar ‘tools’. This paper chronicles the first phase of the research which was established as a feasibility study to ascertain if the target group could benefit from such a product and to receive their input. In so doing it lays out the foundation and philosophies involved.

## **2. BACKGROUND**

At the ‘Year of the Brain’ conference in Aalborg, Denmark, the author presented his ‘SoundScapes’ body of work (Brooks 2003). Prominent figures from two of the leading Centres for Rehabilitation of Brain Injury were in the audience and, understanding the potentials inherent in the concept, they approached the author which resulted in trial sessions being initiated with physiotherapists and acquired brain injured patients. The sessions led to further collaborations and presentations including one where the author won the top European prize at the BAM (Brokerage Applied Multimedia) event hosted by the Eureka organisation in Stockholm, Sweden. The presentation was of his evolving research within the field of special needs and his design of the proposed telehealth system product which is the subject of this paper. Subsequently in a collaborative effort with the same team from the Centre for Rehabilitation of Brain Injury in Copenhagen the project which is covered by this paper was initiated which resulted in a Danish government funding of the study.

The Humanics study that this paper refers to was covered by non-disclosure agreements under the Danish government product development contract until recently (2004) whereupon written clearance was given by the CRBI enabling the author to publish on the project.

### 3. CENTRE FOR REHABILITATION OF BRAIN INJURY (CRBI)

The CRBI was established in Copenhagen, Denmark in 1985 for the rehabilitation of acquired brain injury through holistic & individual treatment with a main focus on return to work and/or improved quality of life. Today, in 2004, it is a self contained entity based at Copenhagen University following in 1993 being awarded the Special Institute Status and accordingly it initiates training, research and education programs. It is one of the top European Centres and the team consisting of Psychologists, Physiotherapists, Neurologists and Speech Therapists is highly respected in the field. The aim of CRBI is stated as:

*Integration through:-*

*'Training and awareness of psychological & physical deficits & strengths' and 'Insight & Compensation techniques'*

### 4. PROJECT CONCEPT

Most people joyously appreciate moving or dancing to music. *Creating* music and images with body movement alone adds a new and different dimension to such joy. Physical rehabilitation after sustained brain injury is often an enduring and cumbersome task to the patient, who is only encouraged if a feeling of progression is present. If productive creativity could supplement such feelings of progression, or perhaps *be the progression*, then physical rehabilitation might be a different, more exiting and inspiring part of life after sustained brain injury. Since creativity, challenge/success and motivation are at the core of the original system, the work also focuses on these (all too often ignored) aspects of rehabilitation. In the same perspective this focus might affect the creativity and motivation with which the patient meets every-day tasks. The aim of the project was to create a home based untraditional IT-system supporting these goals and which would work as a supplement to traditional physiotherapeutic training. This is illustrated in figure 1 where the patient is at the top tested in the clinic and the system calibrated with his specific expected progress data. He takes the system home and trains with the family support and without the stress and costs involved of having to report physically to the clinic daily or weekly. The progress of his home training is sent automatically via the internet to the clinic for monitoring, fine tuning and feedback via web cam & mails.

### 5. CREATIVITY & MOTIVATION

Creativity seems to defy definition and along with motivation is often overlooked in rehabilitation. This means it is often dismissed as a parameter when trying to define measurable goals in rehabilitation (and in many other areas). Yet we know that the feeling of creating something unique or personal is often a source of satisfaction. Thus creativity may well be a source for motivation. In rehabilitation it is clearly apparent, that focusing on improvement promotes motivation for the patient to exercise. With use of feedback to movement of the whole body as well as parts thereof, the project used concepts of music and dance as well as games, tasks and challenges to keep patient's motivation high when 'working out.' A main idea relative to the earlier research by the author is to be able to "hear the way you move" towards an improved proprioception.

### 6. MOTION CAPTURE

'Motion capture' or 'motion tracking' is about capturing human movement and translating it into knowledge about movement efficiency. It is used for example in sports, film animation and rehabilitation. Several different approaches have been used ranging from expensive multi-tracking camera systems (Vicon, Qualisys, SIMI) to more low cost "wearable systems" (DIEM, Troika) connecting to the computer through cables which are encumbering and impractical for rehabilitation. Such camera systems involve 'expert knowledge and training' for operation and typically are located at institutes which are funded accordingly.

The capture system for the Humanics project was conceptualised as a cost-effective sensor/camera system. Parallel studies with camera systems proved fruitful and it seems pertinent to state that the SoundScapes system that was used for this feasibility study utilising only sensors is now a non-tangible system including cameras and sensors as proposed in the author's original Humanics system design.

### 7. SOUNDSCAPES SYSTEM

SoundScapes is a system which consists of a variety of non-wearable movement sensors which register motion. The movement information is routed to a computer, which then transforms the data into sound,

image and coloured light patterns. Thus, the participants receive an immediate feedback on their movements. In this way, the participants have the opportunity to see/hear their pattern of movement and to see/hear which parts of the body they are moving/not moving. Such a feedback can be of singular importance to for instance people with acquired brain injuries with hemipareses with or without neglect. The participants themselves have the opportunity to choose which kinds of feedback they want.

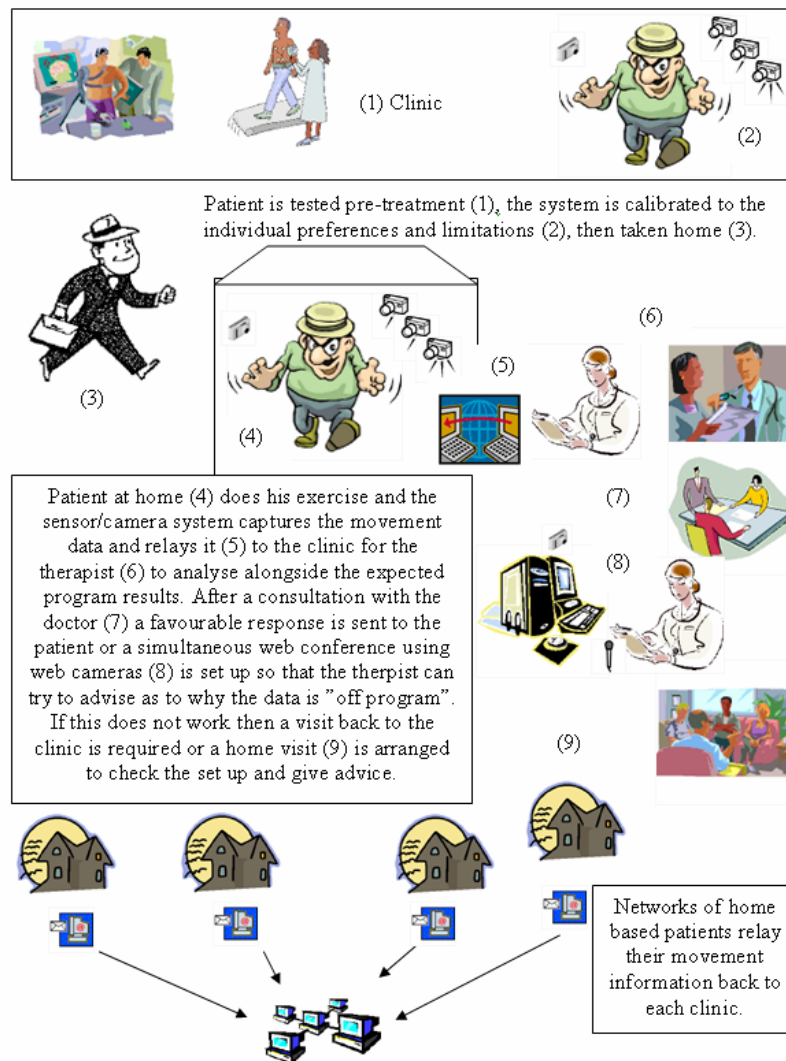


Figure 1. Humanics telehealth system

## 8. RESEARCH OBJECTIVES

The following issues were addressed through the study with the system:

- Does the system give patients with acquired brain injury with physical injuries, an increased physical level of activity and function?
- Does the system have the potential to become a relevant and novel system, and can it increase motivation for physical rehabilitation?
- If the Humanics System is implemented in the patients' home: Is there a potential for increased training efficiency or other benefits by live www-connections between patient and physiotherapist?
- Is implementation of the System as training measurer in private homes a viable prospect?



- When training in the system: Is a more free style of training (e.g. no specific physiotherapeutic exercise or goal) preferable to a more restricted type of training (e.g. specific physiotherapeutic measures and aims, comparing achieved goals, etc.) or vice versa?
- Can results from the system be shown to correlate with functional change measured by traditional physiotherapeutic tests? And if it can; which functions will it be possible/desirable to measure?
- Working with the system: Are creative and motivational aspects of specific activities outside the training sessions affected?

## 9. METHOD (Phase 1)

The single-case feasibility study included 5 adult patients<sup>i</sup> selected among patients formerly enrolled in the CRBI rehabilitation program<sup>ii</sup>. Training with the baseline SoundScapes system was over one 3-week period. During the training period a rehabilitation physiotherapist collaborated with the author to train and introduce all patients in one-hour sessions. Over the three weeks a maximum attendance was 11. Each session consisted of activities for the patients needs. The entire session of phase 1 utilized the SoundScapes system.

All patients are individually tested following the schedule below:

- At inclusion: User Interface Questionnaire / Prior experience with computers (see appendix 3).
- Immediately before and after the training period. Physiotherapeutic testing including tests of general fitness, balance, level of activity, and quality of movement (see appendix 1). Psychological testing of creativity and motivation (see appendix 2).
- At every training session: Multiple camera video recordings<sup>iii</sup> and audio comments taped by the physiotherapist were collected.
- Where possible results from tests carried out immediately after the traditional rehabilitation program at CRBI are used as reference points.

## 10. PATIENT SELECTION FOR HUMANICS

As mentioned potential participants were selected from a group of patients formerly enrolled in the traditional post-acute rehabilitation program at the CRBI. At a very general level patients enrolled in this program are typically ½-3 years post-injury and are able to handle most essential ADL at a reasonable level. A total of 51 adults, 26 male and 25 female patients with acquired brain injury (stroke or trauma) aged 24-62 yrs. were selected as potential participants. Exclusion criteria were inherent cerebral dysfunction, any history of psychiatric disease and substance abuse. All participants continue to have physical impairment following their injury (this means that reduced functions of one or more body parts are observed by means of common clinical, neurological assessment). Time post-injury for most patients was 2-7 years having participated in the rehabilitation program 0-4 years ago. Since the patients of the Centre (CRBI) are among the best functioning 30 per cent of all Danish people with brain injuries, many of them were occupied in jobs in some measure. Measures were taken to create homogenous groups of patients in relation to age, gender and localisation / degree of injury. Focus has been put on the largest possible variation of physical after-effects from the injury/the illness.

## 11. SESSIONS

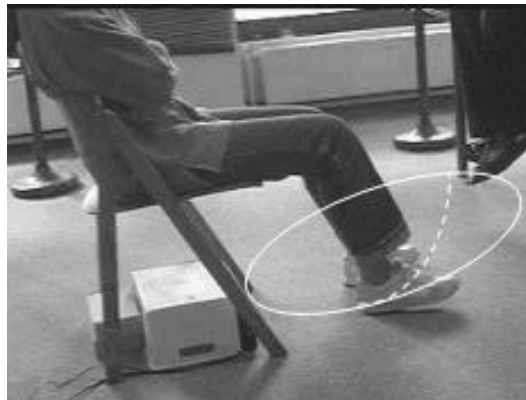
### 11.1 Set up

The SoundScapes system was set up as a makeshift laboratory in a large room in the University of Copenhagen adjacent to CRBI. The equipment was primarily - a PC, a three headed infrared volumetric sensor array (author prototype); an ultrasonic linear sensor (*Soundbeam*); three intelligent robotic light devices; and peripheral interfaces and cabling to source, route and map movement signals into the computer workstation. The protocol of MIDI (Musical Instrument Digital Interface) was the core language.

### 11.2 Training

An intense three week period was scheduled and the participants attended sessions of one hour duration. Some were not able to attend all of the sessions and the maximum attended possible was 11 times. The most was 10 times with the average of the others coming 5 times over the three week period. The exercises were inductively designed relative to each person's damage and preference for limb/functional training. Many of

the improvised exercises proved of great worth and were sustained throughout the period (see 11.3 below.) All were trained with the use of the system giving them an auditive feedback relative to their balance. This was often with the eyes closed which was a problem for many of them and support was required, however they were very positive about this although it was difficult for them. Often they would initiate a sequence of movements that they had previously been instructed to perform or had self-created to help in training. The role of the system in such instances was to give an auditive and/or visual feedback relative to the movement to aid in body awareness. The limbs to be exercised were always located so as to traverse within a Virtual Interactive Space - VIS (Brooks 1999) – volumetric or linear - with a silent ‘rest’ area adjacent.



**Figure 2:** *Extension of leg through interactive sound space exercise: The solid white oval marks the active sense space. The dotted line indicates the foot motion through the active space. The foot starts at the perimeter of the active space and traverses across which results in a scalar tone feedback of a musical instrument, for example a piano. The participant with eyes closed listens to the tone and controls the phrasing and direction of the scale, ascending or descending. This was also programmed to be a familiar melodic tune.*



**Figure 3:** *Balance exercise: Working with the neglected left side of the patient he faces a large reflector on the wall and closes his eyes as he traverses across the invisible active space towards the author who stands by to assist. The white line marks the body points that activate the sounds. This was the best sonic exercise for the male participant as he was incrementally more responsive to visual manipulation as reinforced feedback.*



**Figure 4:** *Cognitive independence exercise: The movement of the hand in the active (white O) space controls the movement and colour of the light (the triangle on the facing wall) and a 'freeze' pedal under the table out of sight of the participant 'freezes' the position. The participant manipulates to a target on the far wall.*

### 11.3 Noteworthy incidences

One patient, 63 years of age male who suffered a haemorrhage in the left side of the brain in 1999 had limited observed auditive response in the sessions (figure 3). He informed us that he was a visual artist who had never had any interest in music, and gave a catalogue of his work to the author as a gift in his second session. One visual piece from the catalogue was replicated by the author on the computer so that the man could move his hands between a red, green, and blue filter opening program sensor array and paint the sequence of images that formed the digital version of his piece of art. A major motivation shift occurred through this for him and it is a good example of how the system has to be capable to immediate change to user preferences.

Other exercises that were notably very successful involved the setting up of a sequence (MIDI) of musical tones that constituted a familiar melody and was playable by event triggering through limb movement. This became a phrasing exercise which enabled control relative to desired goal (see figure 2). Another popular exercise was in using an intelligent light scanner that was interfaced to the sensors so that movement of a limb controlled movement of the light image. In this case, with a task given to move the light to a predetermined target usually high on the far left wall, the participant would move a hand in one sensor space to control the horizontal (X) trajectory; then once satisfied to the strategy, they then had to hold that position and press a 'freeze' pedal which was out of sight under the table. Similarly for the vertical (Y) trajectory a movement, a hold and a 'freeze' pedal press. This was perhaps the greatest success as a cognitive independence exercise which was specifically task oriented with a very physical feedback (see figure 4).

### 11.4 Results

All of those that attended the sessions over the three weeks gave positive response in interviews. They had many ideas following the introduction to the SoundScapes system. Adaptability was a key component so as to be able to fit each individual preferences and limitation. The auditive feedback worked for all but the man who never listened to music mentioned in 11.3 above. All felt that given time they could use the system and thought the home based idea linked by internet a good idea. They also liked the idea of family involvement.

## 12. CONCLUSION

The feasibility study (phase 1) presented in this paper was a seen by the Danish government body and CRBI as a successful first phase towards the design and realisation of a product and the development contract did in fact follow as a result of this initial study. The small number of participants (5), all positive in the interviews, however could be pointed to as insignificant in number for a research study and the 'loose' methodology implemented in the sessions was not conclusive to a 'hard science' result. The limited time frame of sessions with such a diverse group was also a restriction. A subsequent publication will detail the research for the full product development at CRBI where a larger user group was tested over a longer time period in phase 2.

**Acknowledgement:** Notably I would like to mention the CRBI ex-Director M. Pinner and physiotherapist G. Thorsen who were the ‘Year of The Brain’ visitors who initiated the start of the collaboration. Coordinator/secretary L. Lambek, external project coordinator P.K. Larsen, and psychologist E.B. Lyon, all who were with the project for the duration at the Centre - thanks. Others have contributed to the research along the way and whilst I am informed by the CRBI that there is no need to credit names the hard work of Physiotherapist J. Sorensen and Psychologist P. Pipenbring in phase 2 must be mentioned, and similarly H. Mølmark & P. Forster in phase 1. All of the ‘students’ involved in the sessions and all of the staff at the Centre for Rehabilitation of Brain Injury for giving such fantastic hospitality during the collaborative years when I was based there. Thanks to the Danish ‘Erhvervsfremmestyrelsen’ and ‘The Egmont Fund,’ Denmark who were involved in funding the project, also to my equipment sponsors ‘Soundbeam’ of Bristol in the UK, IBM for continued support and Martin Lights Denmark for the gratis loan of equipment.

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## APPENDIX 1: PHYSIOTHERAPEUTIC TESTS

Baseline tests: Carried out after the traditional rehabilitation program at the CRBI - *Repeated* before & after test period.

- Grooved Pegboard (Reitan, *et al.*, 1992.)
- Halstead's Finger tapping test (Reitan, *et al.*, 1992.)
- Åstrands Bicycle ergo meter test – measurement of general fitness (Asmussen, *et al.*, 1980.)
- Brief Fatigue Inventory (BFI) (Mendoza, *et al.*, 1999. See also BFI hyperlink.)
- Joint flexibility of involved joints (Pain inventory). Manually measured (angle) by physiotherapist.
- Measure of strength of involved muscle groups (Pain inventory).
- Functional Quality of Movement (FQM) inventory in ADL (Brown *et al.*, in press).
- Berg Balance Scale - dynamic balance (Berg, *et al.*, 1989 a & b; 1992 a & b; 1995).

## APPENDIX 2: PSYCHOLOGICAL TESTS AND INTERVIEWS

- Rotter's Sentence completion test (Rotter *et al.*, 1947; Gerhardt, 1995.)
- Brick Test<sup>iv</sup>
- The Creative Function Test (Carlsson *et al.*, 2000.)
- Tinker Toy Test (Lezak, 1995.)
- Rosenberg Self-esteem Scale, RSES (Rosenberg, 1965; Crandall, 1973; Wylie, 1974.)
- The Tennessee Self-concept Scale, 2<sup>nd</sup> ed. (Fitts *et al.*, 1996.)
- General Well-Beeing Schedule (Dupuy, 1978, Murrel, 1999.)
- Becks Depression Inventory (Beck, 1961; 1987.)
- Dedicated semi structured interview.
- Focus group interviews including all patients. Led by a psychologist and recorded on video. Experiences, ideas and criticisms are summed up (phase 2 only.)

## APPENDIX 3: USER INTERFACE QUESTIONNAIRE

The Questionnaire was designed with open-end questions especially for use with the Humanics project. It addressed two main areas:

- Prior experience with Computers
- User interface of the system (ease of use, feedback, inspiration)

<sup>i</sup> One child of 8 years of age recovering from a brain tumour operation also came once and was highly motivated, however sadly due to reaction to chemotherapy he had to stop his visits.

<sup>ii</sup> For further description of the CRBI rehabilitation program and patients see Pinner in Christensen *et al.*, 2000

<sup>iii</sup> Evaluation methods pertaining to video recordings - evaluation by 3rd party physiotherapists (minimum of two) are considered the optimal solution.

<sup>iv</sup> This test is often cited as a general measure of creativity. The person being tested is asked within a certain time limit to name as many different purposes for a brick as possible.

*NB. The use of (the author owned) equipment in the feasibility study is credited in the report to the Danish authorities as having belonged to the phase 2 commercial contractor Personics. This is incorrect. TB*

# Play Therapy Utilizing the Sony EyeToy ®

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## Abstract

An international collaborative explorative pilot study is detailed between hospitals in Denmark and Sweden involving rehabilitation medical staff and children where the affordable, popular and commercially available Sony Playstation 2 EyeToy® is used to investigate our goal in enquiring to the potentials of games utilizing mirrored user embodiment in the rapy. Results highlight the positive aspects of gameplay and the evaluand potential in the field. Conclusions suggest a continuum where presence state is a significant interim mode toward a higher order aesthetic resonance state that we claim inherent to our interpretation of play therapy.

**Keywords---** Flow, Therapy, Training, Play.

## 1. Introduction

Our hypothesis is that game playing using embodied user interaction has evaluand potentials in therapy and thus significance in quality of life research for the special needs community. A state of prese nce is inhe rent where stimulation of fantasy andi magination involves engagement and subsequent interaction with a virtual environment (VE). Once this engagement is achieved and sustained we propose that a higher order state is achievable through empowered activity toward a zone of optimized motivation (ZOOM) [1]. This is possible by using an interface to the VE that is empowering without the need for any wearable technology that is deemed encumbering or limiting for the participant. The interface data – participant motion - is mapped to control immediate feedback content that has real world physical traits of response and is interesting, enjoyable, and fun for the participant so that experience and engagement is further enhanced.

Subjective presence has predominantly been investigated in respect of optimal user state in virt ual environments and has been suggested as being increased when interaction techniques are employed that permit the user to engage in whole-body movement [2].

Our findings to date indicate at th e motivational potential from an enhanced state of presence achieved from game environments where the body is used as the interactive unencumbered interface [3, 4, 5, 6, 7].

## 1. 1. Presence and Aesthetic Resonance: as a ‘sense state’ continuum

We are in terested in observed behaviour aspects of presence where there is evidence of only a limited body of research.

Accordingly the case is made for a continuum beyond presence that satisfies our requirement of a pl ay therapy scenario where, from within what is termed a state of aesthetic resonance, we enquire to the potential from game systems with mirrored user embodiment by using the EyeToy®. As a result of this initial pilot enquiry we intend to reach a point from where to launch a fuller investigation with a more optimized environment, method, and analysis design.

Aesthetic Resonance (AR) is when t he response to intent is so immediate and aesthetically pleasing as to make one forget the physical movement (and often effort) involved in the con veying of the intention and is in line with [4, 8].

Within targeted aesthetic resonance our strategy is to approach the same immersive engagement that occurs between a child and a computer video game that is often subject to negativity and reverse the polarity of attitude so that it is positively used to empower activities beyond the usual limits of the special needs participant through encouraging an immersed ‘pla y’ mindset rather tha n a ‘therapy’ mindset which our prior research has shown as optimal [9].

Within this set up the same information that is used as control data to the interactive feedback content is available for simultaneously performance progress monitoring.

System tailoring as a result of observations of user performance – bot h physiological and p sychological – i s opportune with related testing that supplements traditional forms of performance measurement.

This in line with our earlier approach to interaction in virtual environments with acquired brain damage patients [4, 5, 9, 11] and is r elated to a study concerning brain neuroplasticity and associated locomotor recovery of stroke patients that reports on users interacting with games and perceiving the activity not as exercise or thera py, but as play [10].

## 1.2. Play

Most play research informs about its relationship to children's cognitive development, and focuses on solitary play [12]. However, this research does not account for the totality of what is going on between children in situations of *interactive* play therapy. Our play therapy approach is activity driven and the targeted aesthetic resonant state of the user we suggest is beyond the often used all encompassing term of presence.

Significantly, others have approached presence as an activity including video games [13] - but conducted in a laboratory which we question due to the situated effect of the environment on the participants. In previous studies [1] we state that activities always are situated, which underline a complex relationship between the individual, the activity, and the environment as mutually constitutive [14]. Thus a relationship to situated presence is implied as we base our enquiry at locales of predicted use with real users. The goal being exploratory is thus implemented in a pilot study so as to define problem areas to achieve preliminary data on potential of video games in therapy.

## 1.3. Under used resource for therapy

With the advancement in computer vision techniques and camera advancements we claim that systems such as the EyeToy® which focus on the body as the interface are an under resourced opportunity for therapists to include into training as unlike traditional biofeedback systems specific licensing is not required as there are no attachments to the patient. The system also achieves an essential aspect of children's engagement in virtual or real worlds as within our situated interactive therapy space they are 'placed' in the midst of the experience, as in a flow state [15].

We hypothesize that tools such as the EyeToy® have potentials to decrease the physical and cognitive load in a daily physical training regime, and this is central to our concept as the child experiences a proactive multimodal state of presence that encourages an unconscious 'pushing of their limits' that they otherwise would not approach outside of the interactive framework. This supports the statement of iterative human afferent efferent neural loop closure as a result of the motivational feedback and feed-forward interaction. This process is valuable for the child's physical demands in everyday life as the pushing intensifies the child's experience of movements in practice [18].

## 2. Gameplaying and mastery

The investigation presented in this paper addresses the promotion of motivational feedback within empowered gameplaying activities whilst attempting at understanding motivational mechanisms. This is by analyzing the gameplaying as an action where the child's increased skills

in using the video game is viewed as a process of emerged mastery [19] of their 'doings' in a form relating to cycles of action-reaction-interaction. The material of the child's action within this study is the movement as the child masters the computer game by moving the body. In Laban's [18] terminology this is described as an 'effort' and he furthermore underlines the importance of offering the child opportunities to express him- or herself through non-human directed efforts in order to keep and increase the child's immediate spontaneity in the situation (e.g. reactive content that promotes subsequent interaction from the child).

For environments to be supportive in this sense, they must engage the child in challenging ways. Even though environments provide children a sense of challenge, they have to feel that their skills meet the challenges. If there is an imbalance between the challenges and the child's skills the child will become stressed or bored. Play and exploration encourage a sense of flow (immersion in enjoyable activities) that "provides a sense of discovery, a creative feeling of transporting the person into a new reality. It pushed the person to higher levels of performance, and led to previously undreamed-of states of consciousness" [15, p.74]. Optimal experience is also described as "a sense that one's skills are adequate to cope with the challenges at hand, in a goal-directed, rule-bound action system that provides clear clues as to how well one is performing" [15, p.71].

These activities are intrinsically rewarding and the enjoyment derives from the gameplaying activity in itself, which is related to the notion of the Zone of Proximal Development in learning situations [20]. In an explorative manner the child's cycle of movements can be shown to be fluent and intense or segmented without connection.

Laban [18] defines such changes in movements as important as they indicate whether there is a presence or absence of flow from one action and state of mind to another. As such the ZOOM [1] is important in its encouragement of the child's unintentional and/or intentional explorations, without immediate goals as in play, or curious discovery, and as a foundation of evoked interest [21]. This kind of interest indicates that the state of aesthetic resonance facilitates a foundation of creative achievements.

The motivational feedback loop described in this paper is also influenced by Leont'ev's [22] description of the formation of an internal plane. We have chosen to use the term of mastery to describe such processes where emphasis is on how the child's use of the game features leads to development of certain skills rather than on internalization [20], or more generalized abilities.

Thus, gameplaying actions do not need to be conscious, as at a certain level they can be unconscious skills, which, supported by playful aspects of the game, proactively push the child's limits towards new levels of movements.

As a preliminary investigation, we attempt to understand movements according to a semiotic interplay between the child's inner and outer world [23] and relate the understanding to presence, through which spontaneous movement engagement and intensity is assigned [18].

We compare this to Wenger's [24] and Vygotsky's [20] description of emergent development processes. Bigün, Petersson and Dahiya [25] characterize such processes as non-formal, where exploration and curiosity are central conditions, rather than traditional formal training conditions.

The movement cycle of the gameplaying child includes a construal of rhythm. The movement cycle is concentrated on the game's external achievement and by moving the body to achieve the external goal the child relates the inner world to the outer. However, it is not so that every movement unifies the inner and outer worlds, there has to be a "reciprocal stimulation of the inward and outward flow of movement, pervading and animating the whole of the body" [18, p.110] in order to enhance a sense of aesthetic resonance. In this way there is a range of flow through presence, from excitement to stillness, which increases and decreases the child's participation in the gameplaying activity.

This range embraces an orchestration of expanding bodily action in space, or, in terms of Laban [18], includes different trace forms of movements that demands continuity of gestures and it is these gestures that we analyse.

### 3. Method

In consequence with our interpretation of the referenced theories and to fulfil the goals of the investigation we used a triangulation of qualitative methodologies to qualitatively analyze the combined materials from the two hospitals:

- Video observations of children playing with the Keep Up EyeToy® game;
- Interviews with children and facilitators;
- Questionnaires to the facilitators involved;
- Diaries/field notes from the facilitators involved.

The subjects in the studies were 18 children (10 females and 8 males) between the ages of 5 and 12 years, mean age 7.66 years, in 20 gameplaying sessions. The children were selected by the hospitals and were well functioning. The control group was similar children from the hospitals not in sessions [5, 9, 11]. The facilitators involved at the hospital were two play therapists and three doctors.

#### 3.1. Description of material

In 2003 Sony Computer Entertainment Inc. released the EyeToy® as a new video game series for its market leading PlayStation®2 (PS2) platform which is based upon using the player's body movements as the interface to the game.

This controller is unique in concept as all interactions to the game are through the video window rather than through the more common handheld gamepad or joystick device. The system is thus ideal for our enquiry.

The EyeToy® game chosen for this study was called 'Keep Up' due to its immediate action content, built in scoring, and cross gender qualities. A monitoring system based on multiple cameras supplemented so that post session analysis was available.

#### 3.2. Description of procedure

EyeToy® games have 'tasks' for the participants to accomplish. The task within this game is to keep a virtual football - with animated real-world physical properties - 'up' within a virtual environment.

One game sequence is limited to three balls and three minutes.

After three balls, or alternatively three minutes, the game agent turns up and gives the player negative or positive feedback related to the scores of the game. The player can increase or decrease the scores by hitting monkeys and other animated characters with the ball as the game progresses.

At both hospitals the studied activities took place in rooms that also were used for other purposes, such as staff meetings and parent information. The children were not normally playing in this room and the system had to be set up around positional markers on floor and tables.

Parents were approached about the project, informed of the goals, and were asked to give their permission on behalf of their children beforehand.

Following the parents signing their permission the children were also asked to sign their permission to participate.

The process started with positioning the child in the calibration upper torso outline on the screen and after an introduction the game was started.

The gameplaying activity was observed and video recorded by the play therapists and doctors.

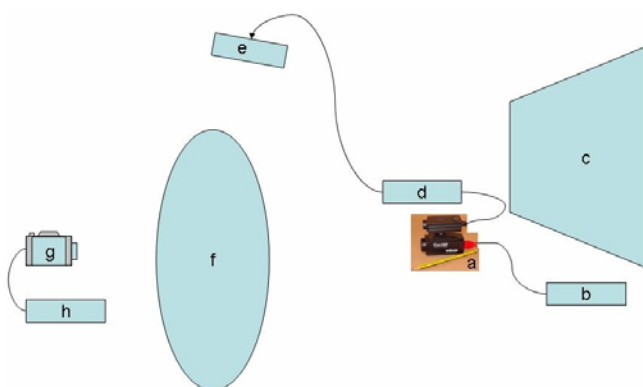
After the ending of the session the children were immediately asked follow up questions concerning their experiences of the gameplaying activity.

After the end of all sessions the play therapists and doctors were asked to fill in a questionnaire concerning their own experiences.

A final interview with the play therapists and doctors was also carried out to conclude the field materials.



### 3.3. Description of the set up



**Figure 1 The set up**

In previous research on camera capture as game interface [6, 10] standard TV monitors were apparently used. Our approach uses a LSD projector for large image projections approaching a 1:1 size ratio of the child (mirroring). This strategy is built upon our prior research investigations [1, 3, 4, 5, 8, 9, 11, 16] to optimize the experience. A related study is reported in the case of presence and screen size [17]. Traditional use of mirroring is used in therapy training at institutes for people with disabilities and thus our design is 'fit appropriate' to this context. Figure 1 (above) demonstrates the set up of the gameplay. The components included in the set up was: (a) EyeToy® camera plus front monitoring camera to capture face and body expression (b) VHS tape recorder (c) screen (d) PS2 (e) projector (f) the user's space (g) rear camera to capture scene and screen (h) VHS tape recorder #2.

### 3.4. Description of analysis

The video recordings underwent numerous temporo-spatial analyses [26] where the units of analysis were the qualitatively different expressions of movement. The material attained from the sessions consisted of 36 x 1 (one) hour mini digital videos (rear and front views) – and corresponding additional backup VHS video tapes - of the 240 video games that were played by the children (n = 18) in 20 sessions at the two hospitals. Each video was digitized for the subsequent analysis; similarly, all video interviews, written notes, memos and written interviews were transcribed and transferred onto a computer workstation.

#### 3.4.1. Manual analysis

Annotation was conducted by two coders. An initial series of four manual annotations of the video materials were conducted. These accounted for observed expressive gesture of the children (facial & body) (see Figure 2, and Appendix 4: Table 3).



**Figure 2 Fully engrossed in the interaction with attention on content**

In addition each video archive game and pause duration was time logged and the first, last, and best performance extracted for later analysis (example charts of three children in Appendix 1: Figure 3). Annotation of parameters of the games and pauses (*between*) before/after best and worst performance were also subject of closer analysis. An extra annotation was carried out on same child multiple sessions (n = 2) including *t* element task scores (ball 1, 2, 3).

The temporal specifics concerns rhythm as a periodic repetition and include dynamic kinetic change as well as structural patterns. Examples of temporal events are the qualities that are in play when the child affects the ball from one spot to another by swinging the body/hands or arms to and fro, which is often a challenge for those with functionality problems. The repetition of a movement develops a sense of enjoyment and engagement of the activity, which, in turn, motivates the child to continue to

experience the movement. Laban [18] states that the repetition creates a memory of the experience, which is needed for new inspiration and insight to develop. More specifically the temporal data was classified into discrete units for analysis by applying the specifics of speed, intensity, and fluency of movements [18, and Efron in 26].

The spatial specifics concerns where the body moves through extended movements towards another situation in the spatial environment. Example of spatial events are the qualities that are in play when the child seeks another situation in the spatial environment, e.g. moving like jumping or leaning the body from one side of the screen to the other whereby the central area of the child's body is transported to a new position when keeping the virtual game ball up in the air. The spatial data was classified into discrete units for analysis by applying the specifics of range and intentionality of movements [18, and Efron in 26]. Alongside with these tempospatial qualities children's face expressions and utterances were analyzed.

Thus, a detailed manual multimodal analysis of the videos was realized so that:

- each video was watched twice before the detailed analysis began;
- the analysis of the first eight videos was realised twice each and the following eight videos once each;
- each minute of video was systematically analysed and transcribed into an excel flowchart in relation to the categories described above. The categories analysed represented high or low degrees of the specific movement trait. This flowchart also included analysis of a facial expression, a description of what happened on the screen (Appendix 4: Table 3);
- every category (n = 8) was analysed separately, which means that the first eight videos were watched in total 18 times each, and the remaining being watched 10 times each. Additionally the multi-sessions were annotated further four times.

### 3.4.2. Computer analysis

Toward a goal to a mass indicators of the overall motion attributes of each child an automated low-level movement analysis was computed on the videos utilising software modules from the 'EyesWeb Gesture Processing Library' specific to the quantity and contraction aspects of the movement<sup>1</sup>. The data was then exported to a spreadsheet for further analysis.

Our strategy for the automated computer video analysis was to supplement the manual annotations toward our overall goal in development of the methodology by (a) following a background subtraction on the source video to

segment the body silhouette a Silhouette Motion Image (SMI) algorithm that is capable of detection of overall quantity, velocity and force of movement is used. Extraction of measures related to the 'temporal dynamics of movement' is computed and a threshold value slider can be adjusted according to each child's functional ability so that he or she is considered to be moving if the area of the motion image is greater than the related (to threshold) percentage of the total area [27]. The adjustment of the threshold value is achieved in real-time annotation of the videos (Appendix 2: Figure 4); (b) a contraction index (CI with range 0-1) algorithm is used with a bounding rectangle that surrounds the 2D silhouette representation of the child within the minimal possible rectangle. The CI is lower if the child has outstretched limbs compared to an image showing the limbs held close to the body where the CI approaches 1 (Appendix 2: Figure 5). Problems were apparent with the child encroaching towards the camera, and background noise. A correcting normalisation algorithm was unsuccessful in correcting the problem and thus refinement is needed [27].

## 4. Results

Our explorative question concerned the potential of video games in therapy and requirements toward a meaningful and optimized full investigation. Our findings present the facts that: (1) more care in the set up of the room background is needed – some videos had curtains blown with wind and people walking behind the child, (2) attire of children should contrast background – if light background and light shirt, then camera software problems occur with differentiating between child and background, (3) lighting of child/room should be optimised, (4) the system is developed for upper torso single person play but many of the children used all of their bodies, especially in kicking when the ball was lower in the screen (5) facilitators should not talk or be in line of sight. Our instructions were also interpreted differently by each hospital in so much that (1) in Sweden a time limit of 10 minutes was established for each session, (2) a long practise period was included within the Swedish ten minute period, (3) in Denmark one of the doctors also included practice periods for his children, (4) in Sweden multiple sessions were held in the same day whilst in Denmark single session per day.

### 4.1. Tempospatial movements

In annotating the games Start – Middle – End segmented zones were interpreted in respect of game and pause data. As expected the best performance was achieved in the end segments on an 8:15:17 ratio (even accounting for extended play boredom through no level change). The

<sup>1</sup> [www.bris.ac.uk/carehere](http://www.bris.ac.uk/carehere) & [www.eyesweb.org](http://www.eyesweb.org)

shortest game ratio was 18:13:9; the longest pause ratio 16:12:12; and the shortest pause ratio 8:14:18.

These figures indicate that the virtual environment interaction with the EyeToy® met with predicted balance of performance and learning curve. Of interest within the figures was the fact that in most cases the best performance was preceded by the child's shortest pause and that following the best game it was often the case that the next two games declined in performance drastically. This matches the manual annotation where the activity (play) peaks and in most cases the emotional expression from face and body gesture before and after relates.

A general result was the faces of the children giving a defined statement of their presence (and aesthetic resonance) in the interaction with the content of the game, which was mostly pleasing and a challenge for their skills.

The detailed analysis showed a connection between temporospatial movements and aesthetic resonance through a correlation between the categories of intensity and intentionality. When there was a high, medium, or low degree of movement intensity, the same degree was always appearing in the category of intentionality of movements. Furthermore, there was a higher degree of aesthetic resonance related to spatial movements than to temporal as the categories of range, intentionality, and shifts had high or medium degree of movements. The categories of speed and fluency, on the other hand, had low or medium degrees of movements, while the degree of intensity in temporal movements was high (Appendix 3, table 2). The computed data analysis supported the manual analysis so as to indicate higher or lower degrees of quantity of movements (QOM) and through the threshold of motion and non motion segmentation (Appendix 2: Figure 4).

Our findings in the multi-sessions were limited to two children. The standard deviation in scores between the sessions is significantly reduced with the girl [duration] 46% [between] 30% [1<sup>st</sup> ball duration] 79% [2<sup>nd</sup> ball duration] 1% [3<sup>rd</sup> ball duration] 49% - the boy, who notably in the first session had an intravenous attachment, showed insignificant change in total. Overall, consistent to our single sessions were reduced 'between' times for both the girl (12%) and the boy (9%) which we claim as a possible indicator of motivation, which we relate to the enjoyment and fun in playing the game. This involves emergent learning of navigation modes and is an attribute to aesthetic resonance through its inherent presence factor. In the multi-sessions we conducted a preliminary computer analysis for duration of last pause and motion phases (Appendix 2: Figure 4). Our findings were that both the girl and the boy had increased standard deviation and average of duration of last pause phase combined with a reduced duration of motion phase from the first to second session. This may indicate that over a number of sessions less motion is required to achieve similar tasks, thus more effective movement is learnt as the child gets acquainted with the

game. Further investigation in relating such findings to presence would seem in order.

To sum up, aesthetic resonance was indicated partly through the high degree of intensity and intentionality in movements. Intensity and intentionality was shown through the children's concentration and also through their force and passion when playing the game. Aesthetic resonance was indicated by the degree of movements of range and shifts in the children's movements. The categories of speed and fluency did not have any influence on aesthetic resonance as they did not influence the intensity, intentionality, range, or shifts in movements.

## 4.2. Interface and activities

In interviews with children concerning their positive and negative experiences of the EyeToy® game the main part of the children expressed positive experiences. 61.1% (n = 11) of the children thought the EyeToy® game was fun, while 22.2% (n = 4) said that they liked it. One (1) child said that the EyeToy® game was difficult, but he also said that the gameplaying was fun. Concerning positive and negative specifics of the gameplay 38.8% (n = 7) of the children answered on the interface attributes and 61.1% (n = 11) on the activity attributes of the game (Table 1). The children's negative experiences of the game only concerned activity attributes regards the content of the game. Two children answered that they enjoyed the whole EyeToy® game. Six children referred to movements – using the body and to move – when they were asked about the positive attributes of the game. Four children said that the ball-play attribute was the best, while seven children stated that the ball-play attribute was the most difficult. These facts indicate that the ball-play attribute in itself was a challenging activity, as three of the children also confirmed.

**Table 1 Attributes**

Positive?			
Interface	Children	Activity	Children
Body used	22.2% (4)	Ball-play	22.2% (4)
To move	11.1% (2)	Monkeys	16.6% (3)
Mirroring	5.5% (1)	Challenge	16.6% (3)
		Scoring	5.5% (1)
SUM	38.8% (7)	SUM	61.1% (11)
Negative?		Difficult?	
Activity	Children	Activity	Children
Monkeys	5.5% (1)	Ball-play	38.3% (7)
Repetition	5.5% (1)		
Pauses	5.5% (1)		
SUM	16.6% (3)	SUM	38.3% (7)

The game agents were the main attributes when the children referred to negative aspects of the EyeToy® game experiences as it repeatedly gave negative feedback to the children. The monkeys were stated as difficult by one child, but were also considered as fun by three of the children.

In summary, the children's experiences of the EyeToy® game indicated that the interface supported the gameplaying activity in a challenging way and aesthetic resonance was achieved through this challenge

## 4.2. Resource for therapy

In interviews and the field notes from the play therapists and the doctors positive, negative, and practical aspects of the children's gameplay with the EyeToy® game was started. They also gave indications on potential with the EyeToy® game in therapy.

### **Positive aspects:**

The EyeToy® game was great fun for the children who were concentrated on the tasks in the game.

### **Negative aspects:**

The children quickly became bored as it was either too hard or too easy to play; three balls were too few; the game ended quickly limiting the challenge; the game agent mostly gave negative feedback, which many of the children commented upon.

### **Practical aspects:**

A room allocated for the test is necessary for future research; the camera set-up was too complicated to handle; the camera set-up limited some of the children's movements; both hospitals wish to continue with future EyeToy® research.

### **Potentials with EyeToy® in therapy:**

The game activity is fun and the training aspect simultaneously involved, becomes fun as well; the game activity brings in movements to the therapy, which make sense and benefits the children's rehabilitation; playing the EyeToy® game becomes physiotherapy; if there was more of challenge and action in the games, the potentials for therapy would increase as the fun and motivation for moving probably would increase.

To sum up, the results from field notes and interviews with the play therapists and doctors underlined the potential with the EyeToy® system in therapy emphasizing flow and fun aspects of the gameplaying as beneficial for the therapy training.

## 5. Discussion

The purpose of the study was to qualify the initial use of the system for children in rehabilitation in a hospital scenario with a consideration of the inherent logistics and practicalities. We restricted our unit of analysis to different expressions of temporospatial movements in process as

indicators of a possible presence state related to behaviour and situation within play therapy. Through our exploratory investigation our findings indicate that aesthetic resonance through intensity and intentionality is related to flow and conscious reactions when a child interacts with the EyeToy® game. Furthermore, presence enhanced aesthetic resonance through range and shift related to movement increments. As far as we can ascertain, the limited computed data supports the manual annotations and our claim where observation of activity mediated within a human afferent efferent neural loop closure as a result of interaction to content of a virtual environment. The field-experiments we consider as a start toward understanding the mechanisms of motivation promoted by multimodal immersion, and the triangulations of actions becoming reactions resulting in interaction in play activities.

## Conclusions

Our approach relates to the heuristic evaluation strategy of Nielsen [28] where natural engagement and interaction to a virtual environment having 'real-world' physical traits and being compatible with user's task and domain is such that expression of natural action and representation to effect responsive artefacts of interesting content feedback encourages a sense of presence. Beyond presence we seek a *sense state* continuum that stimulates intrinsic motivated activity, and from prior research we have termed this aesthetic resonance. To engage an actor in aesthetic resonance we implement a strategy toward creating enjoyment and fun as the user perceived level of interaction where emotional expression of body is the control data of the feedback. In this way an afferent efferent neural feedback loop is established. The data that is controlling the feedback content is available for therapeutic analysis where progression can be monitored and system design adapted to specifics of the task centred training. The user experience however is targeted at being solely play based.

In this document we report on our pilot study which is the first phase of an extended full scale research investigation based on our hypothesis that the positive attributes in utilizing digital interactive games that embody the actor in VE therapy will relegate the negativity tagged to video games and offer new opportunities to supplement traditional therapy training and testing. Our prior research informs that intrinsic motivation is a potential strength of game interaction where the user becomes aware only of the task and in an autotelic manner extends otherwise limiting physical attributes beyond what may otherwise be possible to achieve, and this supports our hypothesis. This study discovered that problems to overcome are the video recording system, the interpretation of instruction, and the room availability. A new single button system for optimizing the video recording system has been designed

and budget planned to improve the next phase of the project. Similarly, the hospitals promise a designated space in future. The children's quantity, dynamic, and range of movements when immersed in the gameplaying activity were over and above their usual range of movements. Their facial expression and emotional outbursts further substantiated our claim that an initial state of presence was achieved.

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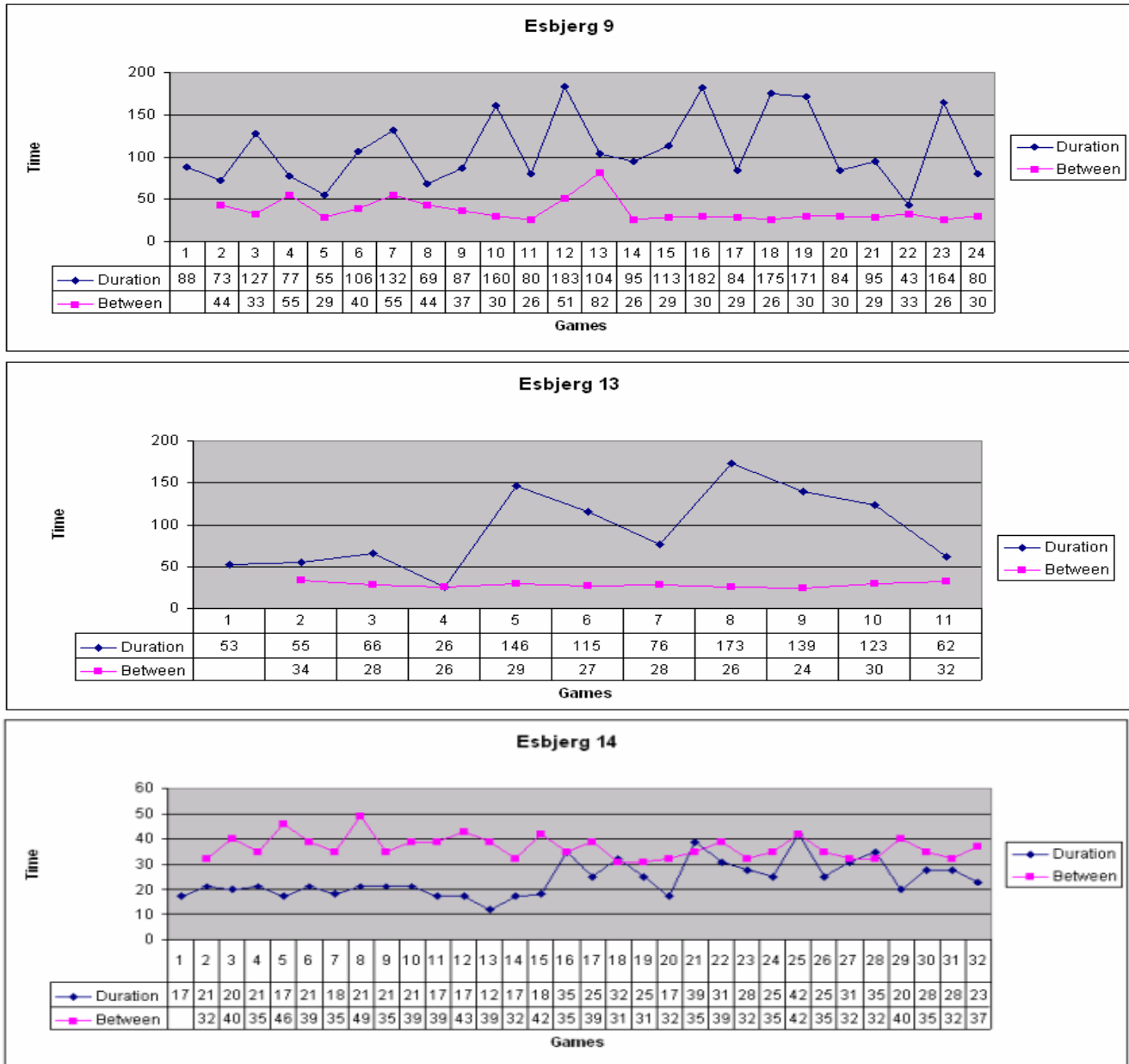
"Playstation" is a registered trademark of Sony Computer Entertainment Inc. "EyeToy" is a registered trademark of Sony Computer Entertainment Europe.

Algorithms adapted from those created with partial support from IST Project CARE HERE where author<sup>1</sup> was researcher [ref - 27].

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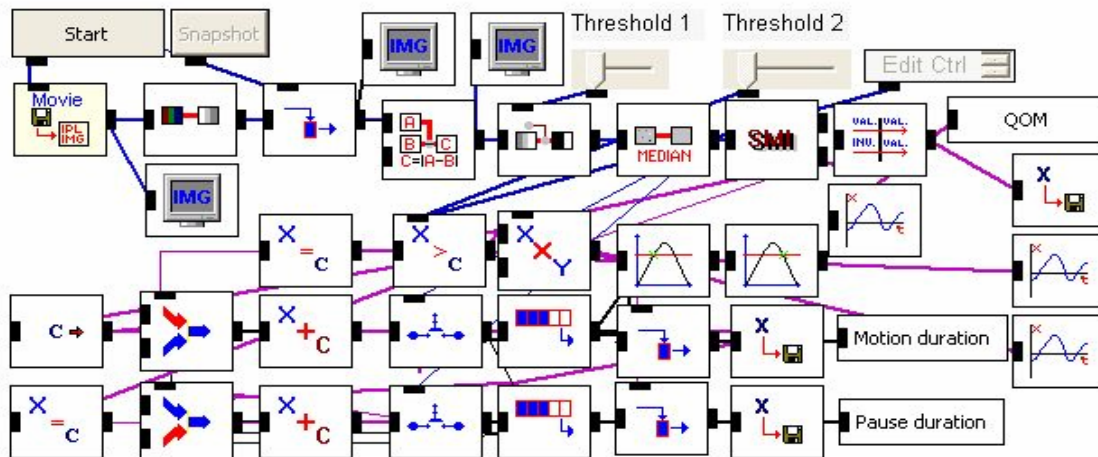
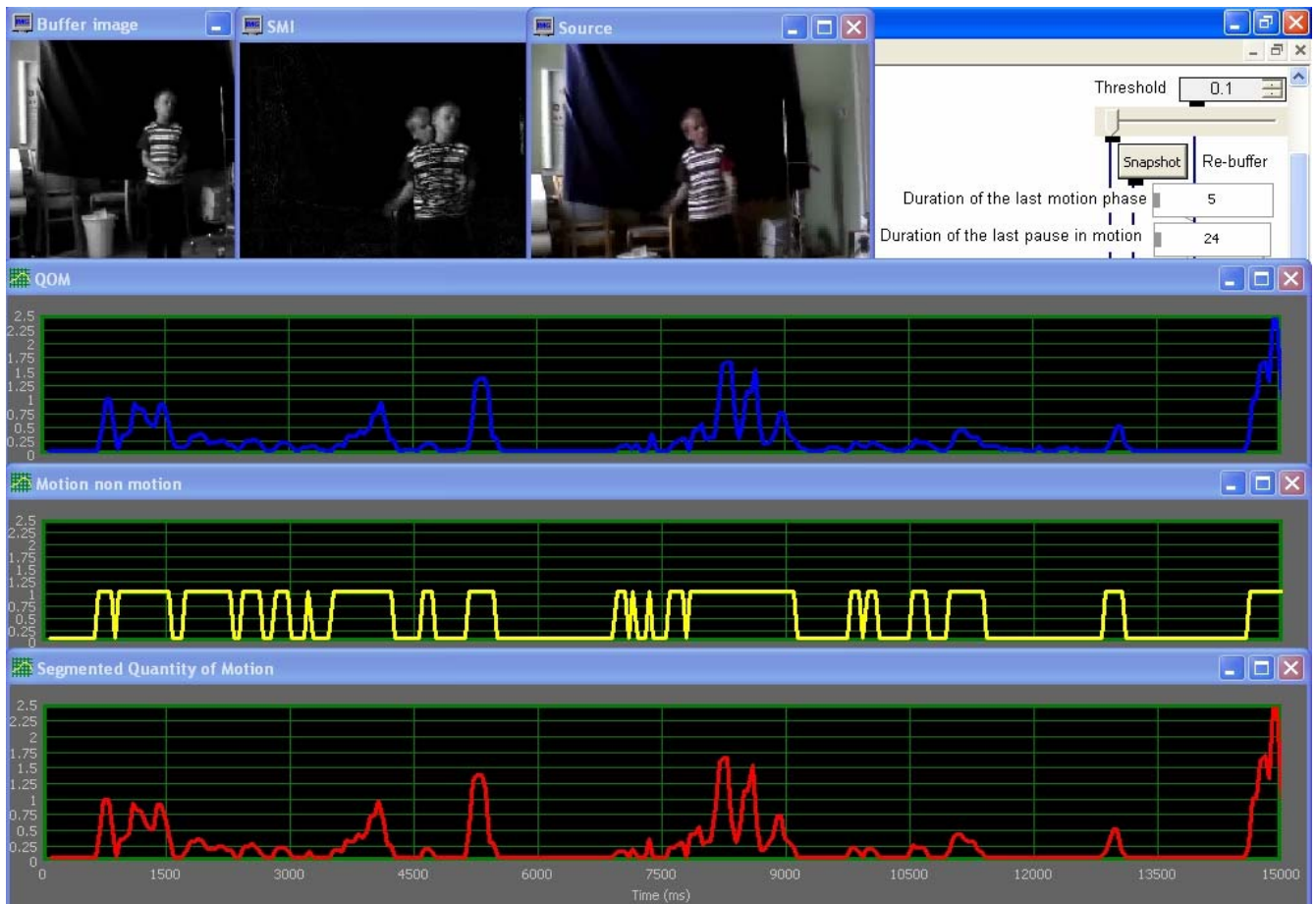
## Appendix 1



**Figure 3** Three examples showing game play results: (top graph) Esbjerg 9 (male 7 years of age) where successes are inconsistent and possibly due to unstable presence. Game 13 is where a higher level was attempted shown by his 'between time' high. Esbjerg 13 (girl of 8 years of age –middle graph) achieved completion of the full game (8<sup>th</sup> game) resulting in an affirmative comment from the game agent. Esbjerg 14 (female 10 years of age – low graph) had most problems (game duration average 24/56.6) this reflective of her functional condition (brain tumor), however she achieved the most number of games (32) whilst continuously pushing her limitations and at conclusion interview described the “great fun” despite her difficulties.



## Appendix 2



**Figure 4 Quantity and segmentation of movement. Threshold/buffer/motion phase indicators (upper right). Buffer image, SMI & source windows (upper left), Halmstad hospital, Sweden. Algorithm for QOM, pause and motion phase duration available from authors.**

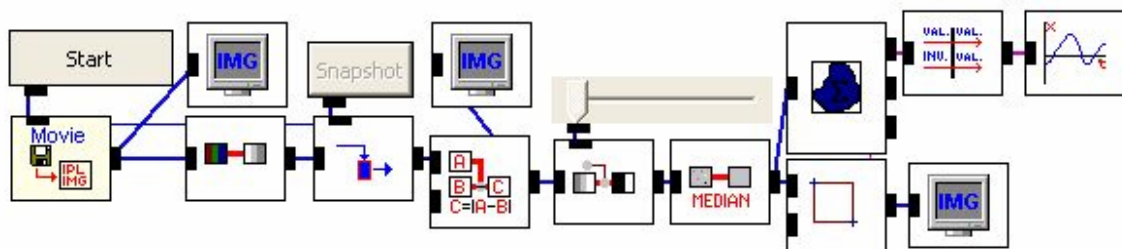
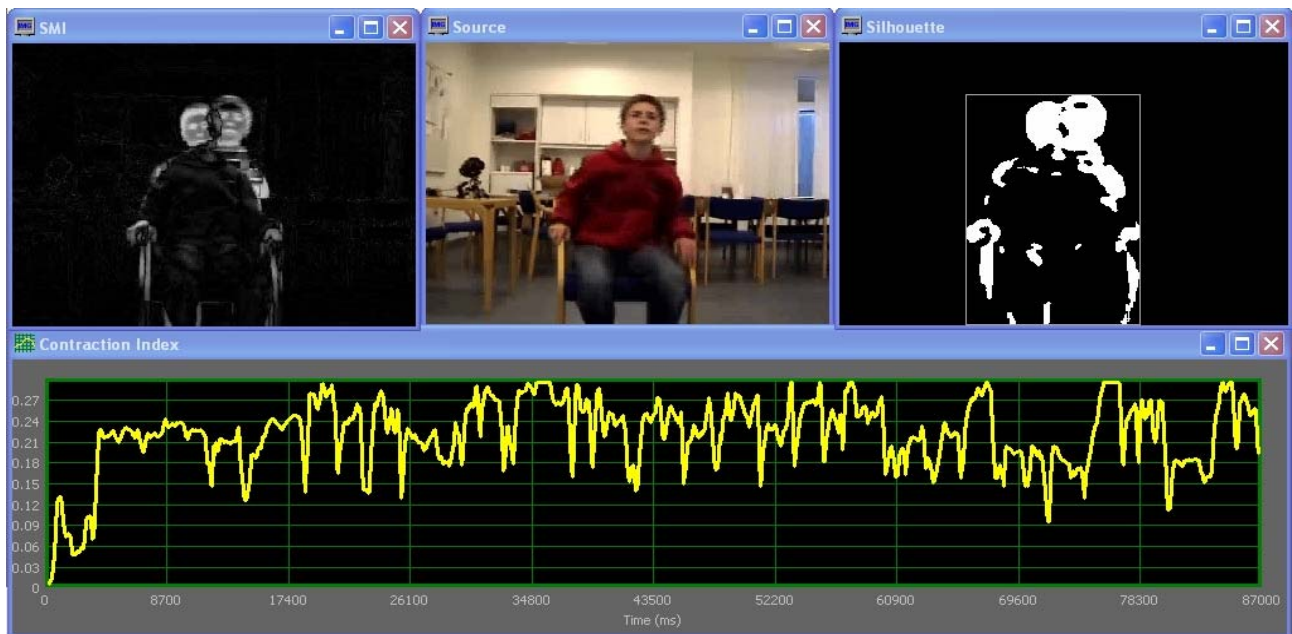


Figure 5 Contraction Index (CI) analysis. Upper right shows silhouette bounding rectangle initially set on buffer image, Esbjerg hospital, Denmark. Algorithm is made available from the authors.

### Appendix 3

Table 2: Session overview: Upper = Sessions/Games (g)/Pauses (p). Lower = Movement analysis

Session	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Total games	16	15	28	10	6	7	13	5	24	14	5	5	11	32	14	8	5	6	8	8
Longest g #	7	13	25	9	4	7	5	5	12	7	3	2	8	25	11	2	1	1	3	5
Shortest g #	1	15	7	4	2	3	9	1	22	1	4	3	4	13	3	1	2	3	7	2
Longest p #	16	8	6	2	5	2	5	2	13	2	3	4	2	8	2	3	5	4	8	6
Shortest p #	4	14	9	9	3	6	8	4	14	13	4	2	9	18	8	4	4	6	5	2
Category of movement trait		High degree (%)					Medium degree (%)					Low degree (%)								
Speed		33.4					22.2					44.4								
Intensity		61.1					16.6					22.3								
Fluency		16.6					55.5					27.9								
Range		72.2					16.6					11.2								
Intentionality		55.5					22.2					22.3								
Shifts		66.6					16.6					16.8								



## Appendix 4.

**Table 3: Temporal Analysis: An example of one annotated session video file.**

Time min.	Temporal						Spatial						Screen
	Speed		Intensity		Fluency		Range		Intentionality		Shift		
	Hi	Lo	Hi	Lo	Hi	Lo	Hi	Lo	Hi	Lo	Hi	Lo	
1		1		1		1		1		1		1	Start screen/Character
2		1		1		1		1		1		1	Wave/Ball/Game Over
3		1	1		1			1	1			1	Character/Wave/Ball/Game Over
4	1		1			1		1	1			1	Ball/Monkeys/Game Over/Character/Wave
5	1		1			1	1			1		1	Wave/Ball/Monkeys
6		1	1			1		1	1			1	Monkeys/Game Over/Character/Wave/Ball
7		1	1			1	1		1			1	Ball/Monkeys/Game Over/Character/Wave
8	1		1			1	1		1			1	Wave/Ball/Monkeys/Game Over
9	1		1			1		1	1		1		Character/Wave/Ball/Monkeys
10	1		1			1	1		1		1		Monkeys/Game Over/Character/Wave
11	1		1			1	1		1		1		Ball/Monkeys
12	1		1			1	1		1		1		Ball/Monkeys/Game Over
13	1		1			1	1		1		1		Character/Wave/Ball/Game Over
14	1		1			1	1		1		1		Character/Wave/Ball/Monkeys (shortly)
15		1	1			1		1	1		1		Monkeys/Game Over/Character/Wave
16	1		1			1	1		1		1		Ball/Monkeys/Game Over/Character/Wave
17	1		1		1		1		1		1		Wave/Ball/Monkeys
18		1	1			1		1	1			1	Monkeys/Game Over/Character/Wave/Ball
19	1			1		1		1		1		1	Ball/Monkeys/Game Over/Character/Wave
20		1	1			1	1		1		1		Wave/Ball/Monkeys/Game Over
21	1			1	1			1		1		1	Character/Wave/Ball/Monkeys
22		1		1		1		1		1		1	Game Over/Character/Wave
23		1		1		1		1		1		1	Ball/Monkeys/Game Over/Character
24		1		1		1		1		1		1	Wave
25		1		1		1	1			1		1	Ball/Monkeys/Game Over
SUM	13	12	17	8	3	22	12	13	16	9	10	15	

# Enhanced gesture capture in virtual interactive space (VIS)

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## Abstract

This article reports on the capture of human movement information which is made possible from a commercially affordable and readily available technology complimented by a simple enhancement which results in an extended *virtual* volume of 3D high resolution activated air being created and available for intervention as a basic computer interface. Through examples presenting the use of the methodology in performance art, education and human performance projects, this article hints at the opportunities from such a methodology so as to inspire others to explore the potential use in human computer interaction (HCI).

Keywords: embodied interaction, presence, sensors

## 1 Introduction

*SoundScapes* is a body of research which includes the creation of an intuitive natural interaction to digital technologies which gives opportunity of expressive freedom through the arts. This is through gesture and body function which inputs 'change' data to a system that is immediately responsive through causal interaction.

This article informs on just one element of the body of research titled *SoundScapes* which the author has been developing since the early 1990s. The holistic body of work has parallel connotations in contemporary performance art, installations, and human performance (therapy and rehabilitation) which are briefly overviewed in the closing sections. Further details are available on the *SoundScapes* website.

### 1.1 History 1920

The creation of electronic music through gesture has been around since the days of the Russian pioneer and physicist Leon Theremin. His main creations, the Theremin and the Terpsitone, are based on the principle of movement within an electromagnetic field producing a monophonic tone with pitch and amplitude being determined by body conductance proximity. His best known creation that he named after himself has been used in hit music recordings and film sound effects where a small hand movement creates a unique analogue tone manipulation in immediate response.

The lesser known Terpsitone system which Leon Theremin created for his dancer

to control sounds and visuals by whole body gesture is more specific to this article and the recent *SoundScapes* body of research (Brooks 2003) which utilize modern day equivalent systems to that implemented by Theremin.

### 1.2 The technology 2004

Commercially available volumetric 3D infrared sensors are used which are stand alone units or inbuilt to equipment created for use by performing artists, disk jockeys (DJs) and video jockeys (VJs). These were originally created by DeFranco in the early 1990s for Interactive Light Corporation and called 'D Beam' (or Dimension Beam) sensors. The sensors are available as single or double emitter heads on standard music equipment made by the Roland ® Corporation who license the technology. A new generation of sensors are available from the original creator at [www.synesthesiacorp.com](http://www.synesthesiacorp.com). The original programmability is that interference in the beam space enables control and manipulate of digital sound. Units were

enhanced in *SoundScapes* by the author so as to additionally control and manipulate image through gesture (Brooks 1999).

The sensor is emitting an infrared beam in the shape of an apple or an onion skin with a 'virtual' core and a multi-skin layer (Figure 1). The beam, existing in the electromagnetic spectrum at a wavelength longer than visible light infrared radiation can be detected but cannot be seen.

The sensor system used is a passive infrared (PIR) system. This infrared sensor technology is sensitive only to reflections of the exact wavelength of IR photons which it is emitting. Any reflective object which enters the volume of space which is an overlap of the emission and detection zones will cause the output signal of the receiver to change by way of reflected photon energy. Movement is not necessary for a signal to be present (thus the enhanced space opportune), but movement results in altering the signal. Human skin has a certain IR reflectivity so it is effective in reflecting photons back to the receiver. Most

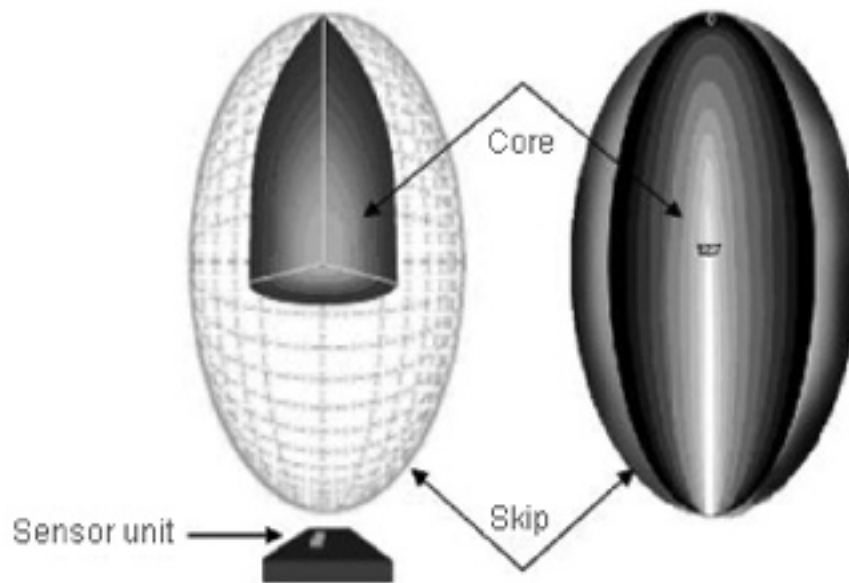


Figure 1. Two diagrammatic views of 3D infrared sensor cross section.

matter has at least some ability to reflect IR, although certain materials can absorb all of it. The system does not see IR emitted from skin surface (heat) because the wavelength of those photons is too long.

The sensor sends, via an emitter, infrared light electrons which reflect off a substrate and can be detected by a receiver located adjacent to the emitter in the sensor head assembly (see Figure 2).

The received interference information is converted into a digital signal for processing and subsequent routing through the unit to exit as a MIDI (Musical Instrument Digital Interface) protocol signal at the sensor unit output.

The sensor, as a motion detector, is looking for rapid change in the amount of reflected photon energy – a variation on the Theremin technique mentioned above based on body conductance – and at high resolution settings it can even detect breathing movement.

The sensor has a lens assembly which focuses and bends the light and gives a pseudo-3D shape to the beam which is experienced in interaction as a volumetric active air space.

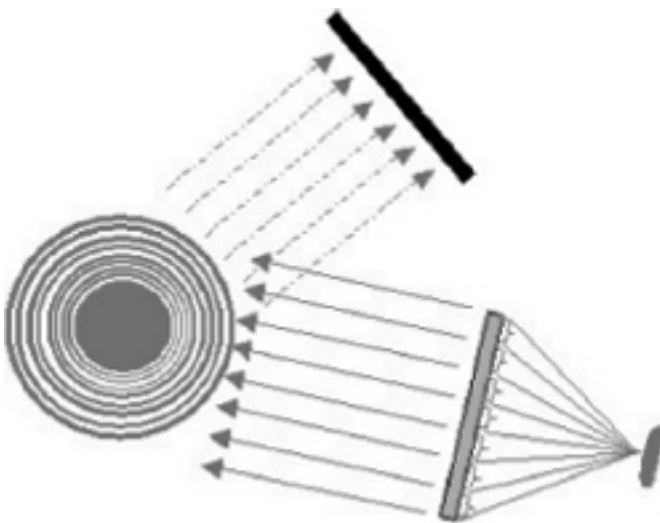


Figure 2. Sensor (emitter lens grey, receiver black).

## 2 Programming and enhancing the space

The skin of the ‘onion shaped beam’ (Figure 1) is programmable for 1) distance from centre and 2) for core size. The data can be event trigger or controller data. This movement change information stream can also be frozen through a footswitch with release on *match of data* or *second switch activation*. Sensitivity can be adjusted for the space to represent between 0 and 127 events (initial trigger at skin); or control information at varying sensitivity, or combinations of these.

Movement of any object capable of reflecting infrared photons entering and traversing the onion shape beam triggers a response as MIDI data. The beam has a skin value and a core value and all values in between. These are programmable so that a MIDI value (0–127) can be assigned to the outer skin and similarly a MIDI value (0–127) can be assigned for the core. Options are to program at source sensor unit (limited to sensor data) or in computer software (sensor data filtered, interpreted and routed).

In the enhance method as described in this article an optimal programming of skin 127 and core 0 (a reversal of usual programming) compensates for the ‘reverse polarity’ of information which is a factor through use of the reflective material changing the extended air space from passive to active.

To extend the space from the original regulated constraints of approximately half a meter above the inbuilt sensor module on the equipment (usually a sound module box) to approximately 12 meters of free volumetric Virtual Interactive Space (VIS) one only needs to use a material called ‘retroreflective microprism’ which is a high reflective paper/cloth used for example in safety apparel. This material is described in the subsequent sections in more detail with considerations for optimal selection.

The enhanced VIS with specific

alternative mapping strategies has been enabled to capture gesture so as to control, for example, robotic interaction (Brooks 2004), navigation in virtual environments (Brooks 2002), and be utilized in telehealth design (Brooks 2004a) and quality of life applications considering people who are handicapped, elderly, and in rehabilitation (Brooks and Hasselblad 2004).

The material can be used in a variety of ways. It can be mounted on a limb whereby if directed to face the sensor emitter/receiver data is captured depending on the movement & mapping. In *SoundScapes* this has been used to emulate a mouse control and Quick Time Virtual Reality (QTVR) navigation, as well as in the creation of a “smart jacket” where half of the jacket was covered with the material so as to enable interactive painting (Brooks 2004b)—however it has a limitation in these modes and necessitates the user ‘wearing’ the material which is against the mission statement of *SoundScapes*.

This use of worn reflective material is also to some degree similar to a method used in high end (cost, training, etc.) body tracking systems where multiple infrared cameras track and plot the information for post session analysis for rehabilitation<sup>1</sup>. However, differing to these referenced systems, the focus with the *SoundScapes* system is to achieve an immediate and direct feedback to the captured movement in real-time which will subsequently motivate and inspire further movements. This occurs in an immersive environment so that the user is directed towards that state which is similar as witnessed in game psychology where a teenager is engrossed beyond anything outside of the virtual world where the interaction is taking place (the monitor). For this an intuitive interaction from body movement to computer feedback is targeted and a corresponding volume of interactive free air is created that enhances and optimises this state.

An ongoing aspect of the research is in fact to quantify aspects of this state so as to further optimize and use across the disciplines where *SoundScapes* is implemented. As such algorithms have been created which enable analysis of movement in real time and post session. Latest news on these issues are through a visit to the research website [www.soundscares.dk](http://www.soundscares.dk).

### 3 Method

A piece of retroreflective microprism material of suitable dimension is mounted onto a wall that faces the sensor head (Figure 3). This is an experimental space as the size and distance of the material from the sensor determines the interaction dimension and sensitivity. The space can be further enhanced with more sensor/material configurations that cross reference (e.g. Figure 4). Such configurations enable a higher resolution of gesture capture. There is no limit on the number of cross referencing units employed which is restrictive when using ultrasound sensors due to cross-noise.

The interaction within the enhanced spaces is through the blocking of the reflected light from the Retroreflective Microprism material by the human body, thus triggering events to be generated in real-time relative to any change in movement.

In other words free air is made to be active in various dimensions so as to control digital multimedia through movement.



Figure 3: VIS enhancement technique (a) sensor head (b) beam dimension without enhancement (c) enhancement retroreflective material (d) approximately 1 meter (e) additional reversed polarity active space of around 12 meters plus.

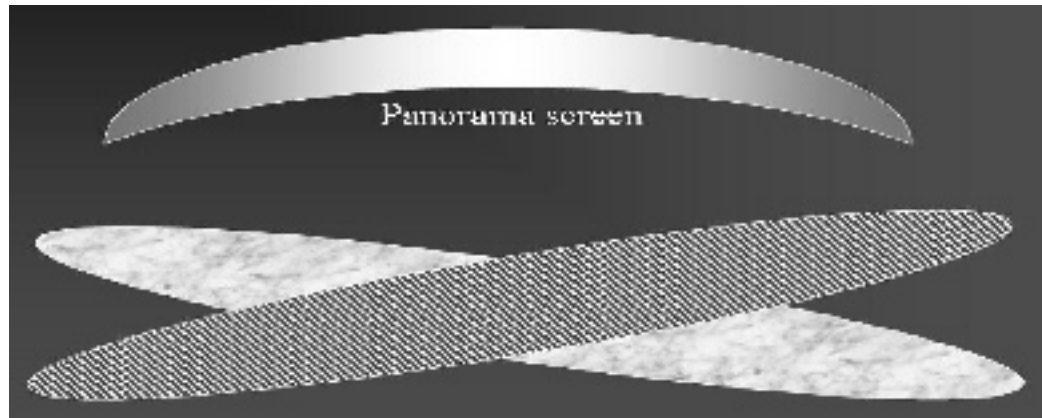


Figure 4: Cross referencing enhanced beam zones (lower elongated ovals) used in this case as a navigational interface for virtual reality from human movement in front of a panorama screen.

Through creative programming the enhanced system can be utilized for other forms of computer interaction such as mouse emulation, game control, and VR navigation. The system is further enhanced through

the development and use of complimentary camera sensor systems and these are included in later sections exemplifying use in public installations, education, public events, and art performance as well as in rehabilitation and therapy.



Figure 5. Human performance training through traversing across working areas of enhanced beam: left = approach from outer left perimeter; right = approach from outer right perimeter; and centre working from the start of blocking of the complete beam.

#### 4 Interaction training

In human performance training (e.g. dance, therapy, rehabilitation, etc.) a user is advised to interact by approaching the space (at highest sensitivity initially) traversing across both perimeters of the long axis so that interference is heard (via the programmed sounds) as the reflected IR photons are blocked (Figure 5).

Subsequent training is in the finding of hot spots so that total blocking of the reflected IR photons is achieved and then a controlled dynamic movement (tilt, rotation, raise, etc.) allows a corresponding number of reflected IR photons to pass the body. Much experimentation is required according to the desires from the interaction.

##### 4.1 The public create the art

In performance art a similar technique is employed as in human performance training.



In installations the spaces are created as dynamic to the public in the space so that ‘the public create the art’. Other uses could be in club events where DJ and VJ decide to capture the movement of dancers which affect the sounds and images that they are dancing to.

This multi-disciplinary approach of performance art supplementing human performance in therapy and rehabilitation at first may seem strange, however if one considers the *Verstehen* (German for ‘empathy’) tradition in realization of the requirement to employ different methods of research, and specific to the *SoundScapes* concept where through utilizing performance art and public interactive installations opportunities are created to study behavioural patterns and subjective aspects of human experience. Furthermore, this research technique in *SoundScapes* is mindful of the arguments from the German sociologist Max Weber (1864-1930) who argued that “if social scientists are to understand the behaviour of individuals and groups, they must learn to “put themselves into the place of the subject of inquiry”. They must gain an understanding of the other’s view of reality, of his or her symbols, values and attitudes.” (Frankfort-Nachmias & Nachmias 1996). This the author attempts through performance

#### 4.2 Retro-reflective technologies

This section details the material used for enhancement and extension of the VIS. Retro-reflective systems are high light reflective surfaces used for example for road safety vehicle marking. There are two major types of retroreflective materials available on the market today—glass bead and microprism. In a glass bead system (Figure 6), light strikes the back surface of the bead and is returned directly to its source. In contrast, light strikes each of the three surfaces of the reflexite microprism (Figure 7) in turn, before returning to its source. Because the microprism provides more reflective surface area than a glass bead,

microprisms reflect up to 250 percent more light than glass beads.

Retroreflective efficiency is enhanced by comparing the random size and placement of the glass beads (6a) with the precise uniformity of the reflexite microprism array



Figure 6  
Glass bead  
retroreflective  
system (a: left,  
b: right).

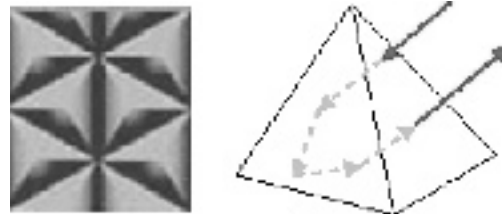


Figure 7.  
Reflexite  
microprism  
retroreflective  
system (a: left,  
b: right).

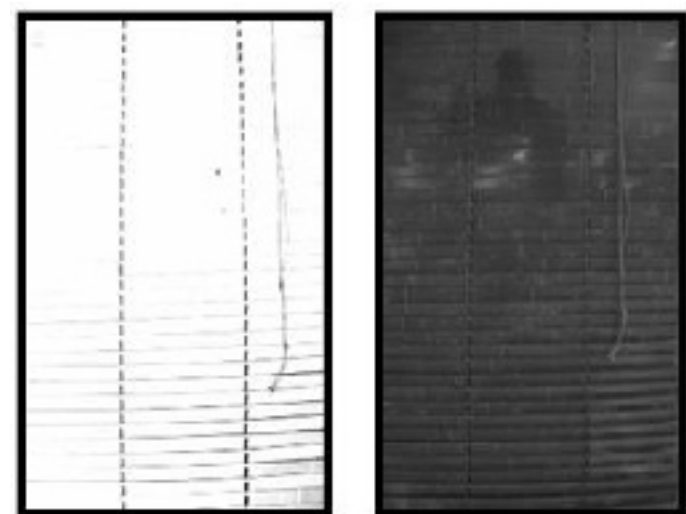


Figure 8. Retroreflective microprism window blind with reflection material stuck onto horizontal slats: As seen by (left) the sensor—(right) the naked eye: Where angle adjustments of the horizontal slats control the amount of reflected photons.

(7a).

The retroreflective micropism material that was found to be optimal in the study is Reflexite GP 800 silver which is high performance retro-reflective material of 'extra class' offering an extremely high specific retro-reflection of 1.000 cd/lux/m measured at 0,2 degree observation angle and + 5 degree entrance angle. This can be used in sheets, dots (wearable) or strips as in Figure 8 stuck onto the horizontal slats of a window blind.

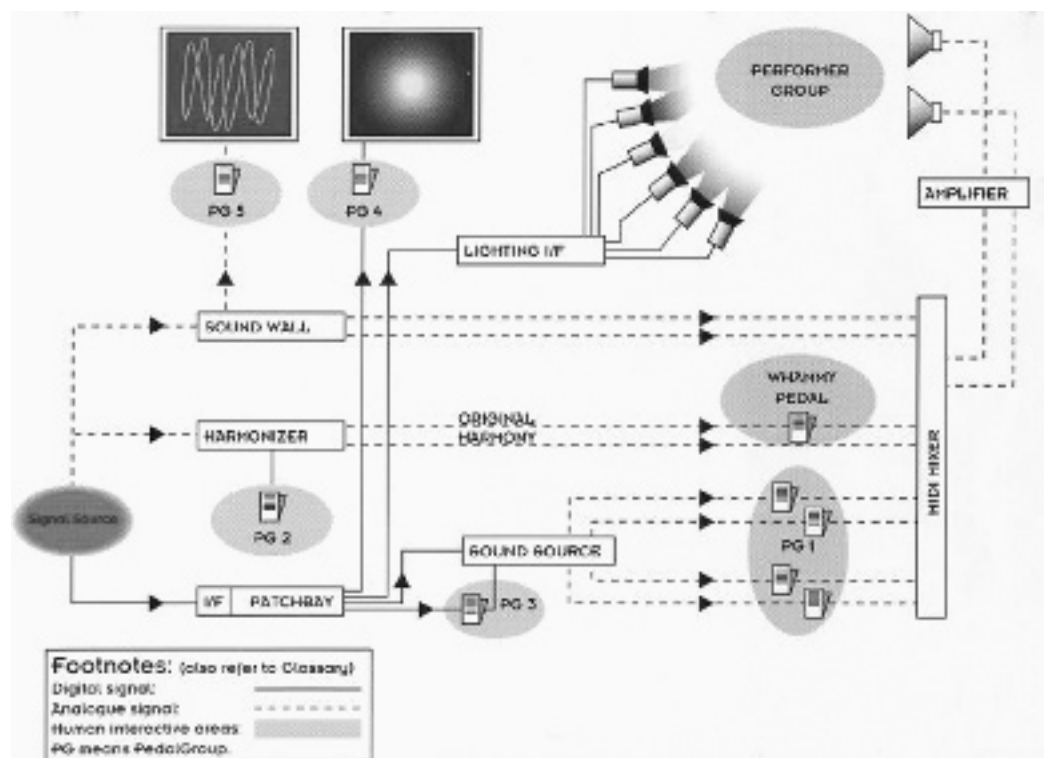
The use of the retroreflective microprism material ‘activates’ the infrared sensor due to the high reflection surface reflecting the IR photons. A window blind is optimal as through adjusting the angle of the horizontal slats that the reflective material is adhered to one can adjust the parameters.

As mentioned previously this

enhancement method to the use of infrared sensor technology has been implemented in various projects and these are briefly overviewed here to give an example of the broad potential applications so as to inspire others to experiment along similar lines.

### 4.3 Contemporary performance art

Performance art is viewed as a perfect vehicle for exploring new research methods as outlined above under the Verstehen tradition. The potential to understand the behaviour of individuals and groups through observation within public interactive installations gives many inspiring insights (see Figure 9). In a similar fashion to this ‘observational mode’ on-stage-performances that are utilising the same techniques can enable the artist to ‘put himself into the space of the perceived





inquiry' i.e. human performance; whereby a form of subliminal physiological immediate self-reflection is suggested—maybe as a subjective responsive cognitive learning?—via the afferent efferent 'body function to multimedia feedback' relationships that are inherently embedded within the interaction. Subsequently, through a form of inductive processing and reflection this modality, in combination with the observational, can be applied within the therapeutic field. This gives opportunities for a new breed of therapist (virtual and real-world) to emerge through artistic intervention whereby gaining an insight at “understanding of the other's view of reality, of his or her symbols, values and attitudes” (Frankfort-Nachmias & Nachmias 1996) so as to improve upon the traditional form.

The history of performance art from the Futurism movement at the turn of the 1900s through to contemporary “Body Art” in the 1960s and beyond hold a fascination freedom of expression that is intrinsic to any artist. Within *SoundScapes* such freedom is positively exemplified through inductive hypothesis which are continuously manifested. As such the scenario where the author places himself into a role of 'performing subject' becomes a learning space for reflection of the grounding of theories that are built within the research process. Weaknesses and strengths become apparent and due to the nature of the experimental form of performance many new layers can be built upon the original design.

On-body biofeedback sensors which captured biological signals (brain waves, muscle tension, galvanic skin response (GSR), heartbeat) and the voice was explored as a layer upon the original design above. Non-tangible sensor technologies were a subsequent additional layer as illustrated in Figure 10.

As camera and computer technologies improved and became more complimentary integrated together a system that focused



Figure 10: Author experimenting with biofeedback sensors and invisible sensor technologies that manipulate sounds, images and physical robotic light effects. Danish TV circa 1995.



Figure 11. Escalator at the Copenhagen Metro



Figure 12. (Left) Enhanced gesture VIS in balance exercise with stroke patient—the white line shows approach to the active sensor space. (Right) Small enhanced space (white oval) for exercise of leg travel (dotted line) and subsequent sonic feedback relative to travel.

on non-wearable VIS interface technologies inductively became the grounded theory of the *SoundScapes* body of research and work.

Installations at Museums of Modern Art (Scandinavia 1998, 1999), the Olympics/Paralympics (Atlanta 1996, Sydney 2000), Danish NeWave (New York 1998), Exit (Sweden 1999) and others, attested to the potential utilization of the model.

#### 4.4 Education

The author is involved in the recently created Mediology and Digital Design educations in Aalborg University Esbjerg (Denmark) where he is employed as an Associate Professor. Within the education students are encouraged to explore creativity integrated with technology and to design and realise in real-world scenarios (with teachers). One of the many interesting projects is one that was designed for the new Metro underground

system in Copenhagen, Denmark. This is a work in progress with the Metro owners' positive as to the realization of the proposal. The design utilizes camera technologies which capture human movement on the down travelling escalators. A screen is facing the escalator and message balloons are shown that are sourced from any selected individual in an attempt to get them to react and communicate together following the escalator travel when they are together on the same lower platform awaiting the subway train to arrive. The illustration in figure 11 shows the concept, which as of writing still awaits a feasibility testing.

#### 4.5 Therapy/rehabilitation

The enhanced VIS under *SoundScapes* has been involved in major funded projects in the field of therapy and rehabilitation, one nationally funded by the Danish government (Brooks and Petersson 2005) illustrated in figure 12 with acquired brain injured patients and one funded by the European Commission under the 6<sup>th</sup> framework IST<sup>2</sup> (Brooks and Hasselblad 2004) with people who are handicapped, elderly and in rehabilitation. As a result of these projects algorithms for quantifying and analysing movement (velocity, duration, phase, quantity, etc.) have been created where camera sensors further enhanced the gesture capture in the VIS. Such analysis is important for progress mapping and system and content design.

#### 4.6 Performance, education and therapy

The final example of implementation of *SoundScapes* is an event illustrating the



Figure 13. Performance group in enhanced VIS, Auckland New Zealand 2002.

potential in an all-encompassing assignment where the author was invited to work with a symphony orchestra, various groups of physically disabled, and two groups of University students, one from an art and design education, and the others from a dance and performance education. This was in Auckland, New Zealand and took place in 2002. It is documented in publication (Brooks 2004b) and online at the MARS (Media Arts and Research studies) Exploratory Media Lab<sup>3</sup> where a search for Four Senses gives access.

## 5 Conclusion

Through the implementation of the described simple system the opportunities of exploration within the arts, design education and social sciences are multiple. The system has attracted much interest from interdisciplinary researchers and is ongoing. Workshops, lectures and presentations are continuous and a new author led and designed complex (The Sensorama) that will host the research is currently (Fall 2004) being built at the Esbjerg campus on the beautiful south west coast of Denmark.

Applied real-world digital creativity offers much potential in human experiences and subsequent quality of life issues for the future across disciplines. What is offered in this article is the author's humble contribution relative to his creative digital vision where art is applied to help people.

The author states that communications in respect of the article are welcome as are proposals for collaborative research. Anyone interested in workshops, presentations or lectures are also welcome to contact the author at the email address given at the title of the paper.

## Acknowledgements

DeFranco, V. Infrared sensor Images (and sensor detail) used with permission. Reflexite Europe, Denmark. Images and information used with permission.

## Notes

<sup>1</sup>Three links to examples of such systems

<http://www.vicon.com/>

<http://www.simi.com/en/>

<http://www.qualisys.com/>

<sup>2</sup>[www.bris.ac.uk/carehere](http://www.bris.ac.uk/carehere)

<sup>3</sup><http://netzspannung.org>

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